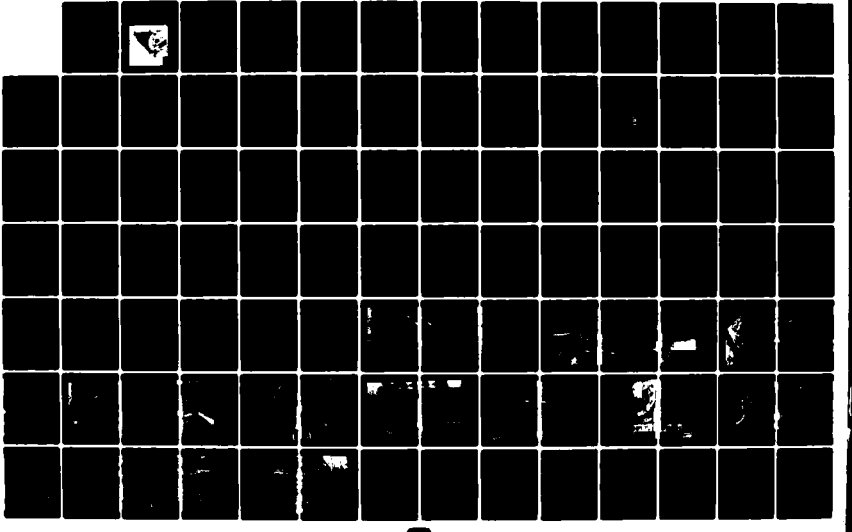
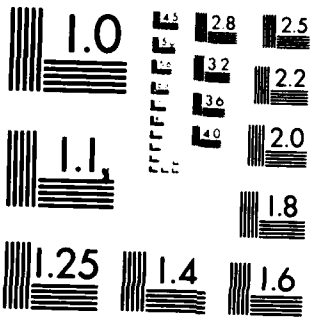
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Colorado River Basin Hoover Dam

Review of Flood Control Regulation

FINAL REPORT
July 1982

U.S. Army Corps of Engineers, Los Angeles District
Bureau of Reclamation, Lower Colorado Region



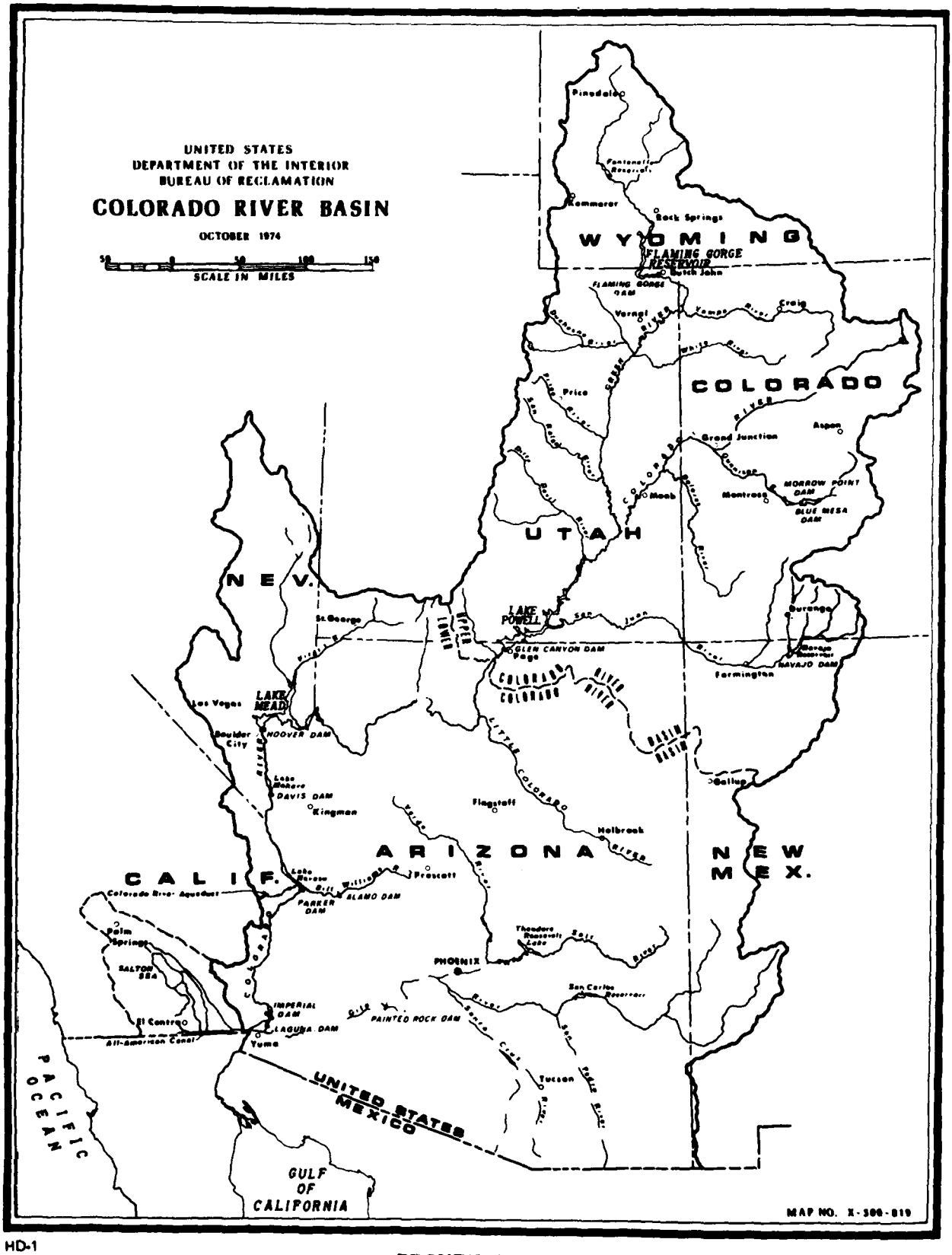
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The purpose of this study is to determine and select the best water control plan for flood control operation of Hoover Dam. The study's scope includes the lower Colorado River flood plain below Hoover Dam including locations in the US and in Mexico, as well as such diverse interests as power markets in Arizona, Nevada, Southern California, Southern Utah, and Western New Mexico; irrigation districts in Arizona and California; municipal water supplies for Las Vegas, Nevada, also for Los Angeles, San Diego, and other cities in SouthernCalifornia; and recreation facilities in all bordering states.

COLORADO RIVER BASIN--HOOVER DAM

REVIEW OF FLOOD CONTROL REGULATION
FINAL REPORT

JULY 1982

U.S. Army Corps of Engineers
Los Angeles District

Bureau of Reclamation
Lower Colorado Region

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Nos. 423-300-1455 and 423-300-1412 through 1434 (23 Sheets)

INTRODUCTION

Flows on the Colorado River below Hoover Dam, following the closure of Glen Canyon Dam in 1963 until May 1979, were limited to water-user requirements plus downstream tributary inflows. The resultant lack of high flows encouraged encroachment of permanent and semipermanent development into portions of the floodway that had at one time served to convey the floodflows. Also, during the period 1963 to June 1980, Lake Powell behind Glen Canyon Dam gradually filled. Consequently, once again there is a high prospect of a need for large flood control releases from Hoover Dam. Because of the above-normal runoff during water year 1980 along with the filling of Lake Powell, releases were made from Hoover Dam in excess of downstream demands to minimize the probability of having to make later mandatory flood control releases that would have been damaging.

The flood control operation plan devised in 1968 was intended to control flooding to the greatest extent possible, with outflows from Hoover Dam limited to 40,000 cubic feet per second (ft^3/s) because a release of 40,000 ft^3/s at that time would have caused minimal damage in the downstream flood plain. Today, however, because of the encroachments into the floodway in the intervening years, a release of 40,000 ft^3/s from Hoover Dam would cause extensive property damage.

PURPOSE AND AUTHORITY

The purpose of this study is to determine and select the best water control plan for flood control operation of Hoover Dam.

The basic authority for this study and report is contained in Section 7 of the Flood Control Act of 1944 (33 U.S.C. sec. 709). This act reads in part:

> Hereinafter, it shall be the duty of the Secretary of War to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds provided on the basis of such purposes, and the operation of any such project shall be in accordance with such regulations * * *.

Rules and regulations (33 C.F.R., sec. 208.11) published in "The Federal Register," Vol. 43, No. 199, Friday, 13 October 1978, provide for the revision of water control plans "* * * to reflect changed conditions that come to bear upon flood control and navigation * * *."

SCOPE OF STUDY

The scope of study includes the Lower Colorado River flood plain below Hoover Dam, as well as such diverse interests as power markets in Arizona, Nevada, southern California, southern Utah, and western New Mexico; irrigation districts in Arizona and California; municipal water supplies for Las Vegas, Nevada, as well as for Los Angeles, San Diego, and other cities in southern California; and recreation beneficiaries in all the bordering states.

This report is based on a study that began in April 1977 for the purpose of providing a sound basis for evaluating alternative flood control operating plans.

Detailed studies for the report were a cooperative effort between the Lower Colorado River Regional Office of the Bureau of Reclamation and the Los Angeles District, Corps of Engineers. The detailed investigations included hydraulic and hydrologic studies, economic studies, environmental studies and mapping of populated areas at Yuma, Blythe, and Needles and the reach between Parker and Parker Dam, commonly known as the Parker Strip. (See location map 423-300-1455 in the section of this report titled "Bureau of Reclamation Maps.") In addition, the International Boundary and Water Commission, United States, and Mexico provided information on the potential impacts of floodflows in Mexico.

Flood frequency studies were based on the modified record of streamflows on the Colorado River. The Bureau of Reclamation, using its Colorado River Storage Project Simulation Model (appendix A), operated on the basic record to produce outflow values that would have occurred at Hoover, Davis, and Parker Dams under the operating conditions of each alternative considered. The Los Angeles District then used the outflow values to develop volume-frequency curves for the Colorado River flows of 1-, 6-, and 12-month duration just below Hoover and Parker Dams and at Blythe, California, and Yuma, Arizona, for each alternative. Only flows passing through Hoover Dam were included in the frequency curves.

Adding downstream tributary flows (pl. 1) to the released flows from Hoover Dam was considered during the study. However, no rational method for combining these flows for all locations along the Lower Colorado River could be devised nor would their effect on plan selection be important. Because of the high degree of control of the Bill Williams River by Alamo Dam, the effect of this large tributary on Lower Colorado River flows is small. The effect of uncontrolled tributaries, including the large drainage area of the Gila River below Painted Rock Dam, on Colorado River flows downstream from Hoover Dam would be to increase short-term peaks for short distances downstream from the tributary mouths. Although the effects of the uncontrolled tributaries on the volume-frequency curves for Hoover Dam releases would be small, and therefore, are not highly significant for this study, they should not be overlooked when short-term peak flooding problems are considered for flood plain management purposes. In general, travel times of flows

from Hoover Dam are too long to permit the operation of Hoover Dam to mitigate the impacts of short-term tributary inflows. Releases that would be additive to tributary peaks would already be in the river by the time the tributary peak was recognized.

The Los Angeles District used the HEC-2 backwater computer program to perform the hydraulic studies to determine the areas subject to flooding by several sizes of floods along the Lower Colorado River. Detailed topography (scale of 1 in. = 100 ft, 2-ft contours) was developed to determine areas subject to flooding in the populated areas at Yuma, Blythe, and Needles, and between Parker and Parker Dam. The Bureau of Reclamation provided areas of inundation for less populated areas, and these were developed with the use of existing cross-section and water-surface-profile data and the U.S. Geological Survey quadrangle maps (1 in. = 2,000 ft) and Bureau of Reclamation orthophotomaps (1 in. = 2,000 ft). The areas of inundation maps were used to determine damage-discharge relationships for the economic studies.

Economic studies included the determination of benefits (hydropower, water conservation, salinity reduction, and flood damage reduction) that would result from implementing each alternative. The Bureau of Reclamation determined the hydropower, water conservation, operation and maintenance, and salinity benefits; and the Los Angeles District, Corps of Engineers, estimated the flood damages. The benefits were used to compare the relative economic merits of the alternatives.

The Bureau of Reclamation conducted studies to determine the environmental impacts of the various alternatives; and furnished its "Environmental Assessment on Alternative Hoover Dam Flood Control Operating Criteria, and Finding of No Significant Impact" for inclusion into this report as appendix E. Extensive existing data from USBR files, including vegetation maps, mammal and bird counts, and cultural survey reports, formed the basis for an inventory of natural and cultural resources.

Aerial topography obtained along four of the more populated reaches of the river was used to determine detailed inundation areas for economic studies. These four reaches included:

a. One reach about 17 miles long from Parker Dam to just downstream from Parker, Arizona.
b. A second reach about 7.5 miles long from about 5 miles upstream to about 2.5 miles downstream from Needles, California.
c. A third reach about 9 miles long from about 3.5 miles upstream to about 5.5 miles downstream from Blythe, California.
d. A fourth reach about 7 miles long from just upstream to about 5.5 miles downstream from Yuma, Arizona.

The aerial topography was plotted on maps at a scale of 1 in. = 100 ft with 2-ft contours.

Nothing in this report is intended to interpret the provisions of the Colorado River Compact (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Water Treaty of 1944 with the United Mexican States (Treaty Series 994, 59 Stat. 1219), the decree entered by the Supreme Court of the United States in Arizona v. California, et al. (376 U.S. 340), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act (70 Stat. 105; 43 U.S.C. 620), or the Colorado River Basin Project Act (82 Stat. 885; 43 U.S.C. 1501).

STUDY PARTICIPANTS AND COORDINATION

The Lower Colorado Regional Office of the Bureau of Reclamation and the Los Angeles District, Corps of Engineers were jointly responsible for planning and carrying out the detailed studies for this report. Periodic working-level meetings provided the primary coordination between the two responsible agencies, and were also attended regularly by a representative of the United States Section of the International Boundary and Water Commission to assure that conduct of the study and its results would be consistent with the United States Government's water and boundary treaties and agreements with Mexico. Also in attendance at these meetings at various times were representatives of the States of Arizona, California, and Nevada, the Upper Colorado Regional Office and the Engineering and Research Center of the Bureau of Reclamation; and the U.S. Geological Survey.

The study was announced in the following three ways:

a. A letter signed jointly by the Regional Director of the Lower Colorado Region, Bureau of Reclamation, and the District Engineer of the Los Angeles District, Corps of Engineers.

b. A news release.

c. A brochure, dated March 1977 and titled "High Water in the Colorado River?"

The letter, distributed to governmental agencies (Federal, State, and local), irrigation districts, and tribal councils in the Lower Colorado River Basin, explained briefly the need for the study and solicited comments and suggestions on identifying impacts, developing alternatives, and accomplishing public involvement. The news release, distributed to newspapers and radio and television stations throughout the Lower Colorado River Basin and to areas of potential interest outside the basin, was aimed at a much broader public and explained the problem briefly and solicited comments. The brochure, designed by the Bureau of Reclamation, provided a fairly detailed description of the problems for the general public.

During the study, six public meetings were held at Needles, Blythe, and Los Angeles, California; and Parker, Yuma, and Phoenix, Arizona. Subsequent meetings were held with agencies having fish and wildlife responsibilities; three Indian groups (Cocopah, Quechan, and Colorado Indian Reservation); the Upper Colorado River Commission; and the State of Arizona, Division of Emergency Services. The meetings were held for the purposes of: explaining and quantifying the problem in detail; presenting plans formulated to that point in time and their impacts; and soliciting (a) comments on those plans and (b) suggestions for alternative plans.

PRIOR STUDIES AND REPORTS

Although many reports concerning studies of the Colorado River have been written, only those that are most germane to determining the best flood control operation for Hoover Dam and Lake Mead are described here.

The Los Angeles District's "Report on Reservoir Regulation for Flood Control - Storage at Hoover Dam and Lake Mead," completed in September 1955 and revised in November 1968, established the fundamental flood control operation criteria upon which all subsequent operational alternatives were based.

The first formal report that specifically addressed the filling of upstream reservoirs and the growing potential for large flood control releases from Hoover Dam was titled "River Flows Between Davis Dam and Yuma, Arizona, Lower Colorado River, A Forecast of Conditions and Impacts for the Period 1977 to 1986," published in October 1976 by the Bureau of Reclamation.

This same agency's series of four flood plain information (FPI) reports published between 1969 and 1974 covered most of the Colorado River below Hoover Dam. The reaches covered and the publication dates of these reports are: Davis Dam to Topock, March 1969; Parker Dam to Headgate Rock Dam, July 1971; Palo Verde Dam to Imperial Dam, October 1974; and Imperial Dam to San Luis, August 1973. These FPI reports establish the "levee design flood" as the basic planning flood; that is, future development should be protected from the levee design flood, and structural flood protection works should be designed to control the levee design flood.

In January 1977, the Bureau of Reclamation published a report, titled "Economic Effects on Riparian Facilities of Increased Overflows in the Colorado River." This report was a limited attempt at establishing the magnitude of flood damages that might be caused by flood control releases at Hoover Dam.

Reports published every 2 years by the Bureau of Reclamation cover the status of the agency's long-term study for the improvement of the quality of Colorado River water. The program emphasizes the monitoring and evaluation of control measures for salinity--the major water quality problem in the river.

THE REPORT

This report is comprised of a main report and pertinent appendixes. The main report summarizes the results of the study in nontechnical fashion and recommends a flood control operation plan for Hoover Dam. The appendixes discuss engineering aspects of the study, describe existing river works along the Lower Colorado River, evaluate economically the alternative plans, evaluate the threat of Colorado River overflows from Mexico into the United States, and provide a Finding of No Significant Impact and an Environmental Assessment. The appendixes also include the text of the recommended Field Working Agreement between the Department of the Interior, Bureau of Reclamation, and the Department of the Army, Corps of Engineers, Regarding Flood Control Operation of Hoover Dam and Lake Mead, Colorado River, Nevada-Arizona; and, in addition, agency views and responses.

RESOURCES AND ECONOMY OF THE STUDY AREA

The geographic area addressed in this study is composed of two disparate parts: (a) the flood plain of the Lower Colorado River and (b) the market areas that are the beneficiaries of Colorado River-produced hydropower, diversions of Colorado River water for consumptive uses, and Colorado River-based recreation, which attracts participants from hundreds of miles away. Even a cursory observation shows that the Colorado River is not only the dominant economic force in the Lower Colorado River Basin, but it is also an extremely important resource to much of the southwest United States.

ENVIRONMENTAL SETTING AND NATURAL RESOURCES

Most of the Colorado River Basin below Hoover Dam is composed entirely of desert. Downstream from Lake Mead and Hoover Dam, the river passes alternately through narrow canyon defiles and broad valleys. The canyons are formed by steep, rugged, and rather barren hills and low mountains. The same type of terrain frames the valleys except in the south near Yuma where the valley broadens substantially.

The climate of the flood plain of the Lower Colorado River is notable for its lack of precipitation and high summer temperatures, routinely exceeding 100° F. Temperatures above 120° have been recorded in the lower basin. Mean annual precipitation ranges from less than 3.5 inches per year in Yuma to about 6 inches per year near Hoover Dam.

The flood plain of the Lower Colorado River contains a variety of natural vegetation. Three different and distinct deserts--the Mohave, the Western Sonora, and the Eastern Sonora--merge in the flood plain. Many of the desert plant species, such as creosote bush, mesquite, salt bush, and ironwood, are common to more than one of the contributing deserts. Each of the deserts, however, makes its own peculiar contributions. The giant saguaro cactus and ocotillo grow in the Eastern Sonora desert; the Mohave desert is noted for its Joshua trees; and the Western Sonora produces palo verde trees, smoke trees, and desert willow.

The Colorado River itself compliments the biotic community of the flood plain by supporting large riparian and phreatophytic (dependent on ground water) vegetation subcommunities. At various locations along the river, marshes support cattail, bulrush, reeds, and willows. Much of the river is lined along its banks with tamarisk (salt cedar), cottonwood trees, and other phreatophytes. Depending on topography, soil conditions, and the extent of disturbance by man, the strips of phreatophytes can range from less than 100 to thousands of feet wide.

Wildlife in the flood plain of the Lower Colorado River is as diverse as its vegetation, once again due in part to the influence of the river. Without the river, the wildlife community would be limited to those species that can survive in a harsh desert atmosphere of searing temperatures and desiccating dryness. The flood plain of the Lower Colorado River supports the entire spectrum of insects, arthropods, mammals, reptiles, and birds that are adapted to living in the deserts of the southwest. This desert wildlife population is greatly augmented by many species dependent upon the food and cover provided by vegetation supported by the river. The availability of surface water in the Colorado River further expands the wildlife community by supporting fish, waterfowl, amphibians, and water-oriented mammals such as racoon and muskrat. The environmental assessment included in this report provides a limited inventory of the wildlife inhabiting the Lower Colorado River.

The principal natural resources of the Lower Colorado River flood plain exploitable by man are soil, water, and climate. Through countless years of untamed flooding and meandering, the Colorado River and its major tributaries laid down broad plains of fertile alluvial soils in the deserts of California and Arizona. Today, these rivers are extensively controlled and provide the vital irrigation water that supports a vast agricultural industry. The waters of the Lower Colorado are further exploited to produce hydropower and to support thirsty urban populations from as far away as Los Angeles and San Diego, California, and soon Phoenix, Arizona. Recreational activities, such as swimming, boating, camping, fishing, and water skiing, which are directly dependent on Colorado River water, rival agriculture in economic importance in the Lower Colorado River Basin.

The climate of the southwest deserts provides one of the longest growing seasons in the world, with frost a rarity. For those who wish to enjoy it, there are the cooling waters of the river and its shading vegetation along with the summer sunshine and clear skies of the region. Warm winter temperatures permit fishing and camping in relative comfort.

ECONOMIC DEVELOPMENT IN THE FLOOD PLAIN

In general, the economic development in the study area is oriented to the river. Along the length of the Lower Colorado River, there are four main regimes of development: agriculture, recreation, tourism, and retirement. These are present in various combinations in the study area, with some aspects of each present in all reaches. The predominant incidence of agriculture is on the Indian Reservations, in the Palo Verde Valley (Blythe), and in the flood plain area of Yuma. The Parker Strip (between Parker Dam and the town of Parker) is the most intensively developed recreational area. Many, if not most, of the residences along this area are either retirement homes or second (vacation) homes. Blythe and Needles both benefit greatly from the tourist traffic along Interstate Highways 10 and 40, respectively. Of the two towns, Needles is the most dependent on tourist traffic.

ECONOMIC OPERATIONS OUTSIDE THE FLOOD PLAIN

The economic importance of the Lower Colorado River extends far beyond its flood plain. Water from the river supports hundreds of thousands of irrigated acres in Nevada, Arizona, and California. Some of the most productive agricultural areas in the nation are located in the Lower Colorado River Basin around the centers of Blythe, Needles, and the Imperial Valley in California; and the Parker Valley and Yuma in Arizona. The production of this vast agricultural complex, worth billions of dollars each year, is almost totally dependent on Colorado River water.

The Lower Colorado River is also an important source of municipal and industrial water for many communities in Nevada, Arizona, and California. The Metropolitan Water District of Southern California, which serves much of the metropolitan area around Los Angeles, is one of the larger customers for municipal and industrial use of Lower Colorado River water.

Relatively inexpensive hydroelectric power produced by power plants at Hoover, Davis, and Parker Dams is another Lower Colorado River resource of great importance outside the flood plain. In 1977, over 3,820 million kilowatt hours of power were produced at Hoover Dam. Additionally, 1,262 million kilowatt hours were produced at the Parker-Davis complex. Customers in California, Arizona, and Nevada paid in excess of $21 million for hydropower from Hoover, Davis, and Parker Dams in 1977. Customers for this hydropower included such cities as Burbank, Glendale, and Pasadena, California, and Boulder City, Nevada; military installations, irrigation districts, and Indian reservations; Arizona Power Pooling Authority; Division of Colorado River Resources, State of Nevada; Los Angeles Department of Water and Power; Metropolitan Water District of Los Angeles; Southern California Edison; and others.

Assessing the economic impact of recreation based on the Colorado River outside the flood plain is more difficult than for water supplies and power generation. If the river-based recreation were not available, many of the recreational dollars would be spent on other recreational alternatives. However, the great extent and distinct character of the riverine recreation may well promote a net increase in recreational expenditures, some of which occur outside the flood plain. The river certainly influences the type of recreational expenditures. Power boats and boat trailers, dune buggies, water skis, fishing tackle, campers, and tents are all routinely purchased in Los Angeles, and Phoenix, and in smaller towns in California, Arizona, and Nevada for use on the Colorado River. Finding alternate sites within an easy day's drive for the use of such equipment would not be an easy task.

PROBLEMS, NEEDS, AND OPPORTUNITIES

This section identifies and discusses the problems and needs of the study area. All the problems, needs, and opportunities normally associated with water resources development, water conservation, hydroelectric power generation, recreation, protection of wildlife resources, flooding, and water quality are extant in the study and all have been addressed in the past through various treaties, laws, court decisions, agreements, structural measures, and practices. Past measures have, in a sense, become part of the current "problem" since they must be taken into account in future planning efforts.

EXISTING PLANS AND IMPROVEMENTS

Understanding the range of water resource problems along the Colorado River and the relationship of the problems to each other requires some knowledge of the existing improvements and facilities along the river. Some of the requisite background knowledge was provided in a previous section of this report titled "Resources and Economy of the Study Area." The following paragraphs describe and discuss specific structures related to water resources.

Numerous dams and reservoirs have been constructed on the Colorado River and its tributaries. Table 1 lists the more pertinent structures along with their purposes and other information. The frontispiece shows the locations of the dams and reservoirs.

In addition to the storage dams listed in table 1, several diversion dams direct water from the Lower Colorado River into canal systems serving various areas in the lower basin. Headgate Rock Dam, located near Parker, Arizona (pl. 1), diverts water to serve Parker Valley. The Palo Verde Diversion Dam regulates flows to canals in the area of Blythe, California. Imperial Dam controls diversions into an elaborate system of canals that serves both sides of the river in the Yuma area, as well as the vast agricultural complex of the Imperial Valley in southern California.

The construction of dams on the Colorado River resulted in secondary problems that have assumed great importance. Although the flow of the river had been regulated, instability of the river channel itself had not. Consequently, the river itself had to undergo significant changes as it adjusted to its new environment. Each reservoir, acting as a sediment trap, cleared up the muddy water and released clear water, which then picked up sediment that had been deposited by earlier floods. The sediment thus picked up moved downstream and was deposited on the riverbed in the slow-moving water at the head of the next reservoir. Thus the reaches of the river below the dams were scoured and deepened whereas other reaches like Topock Gorge and the reach of the river above Imperial Dam were raised by extensive sediment deposits.

Table 1. Dams and reservoirs in the Colorado River Basin.

Name Dam/reservoir	Stream (State)	Owner	Purposes	Maximum active storage of dam/reservoir (Ac-ft)
Upper Basin				
Fontenelle Res.	Green R. (Wyoming)	USBR	Power, flood control, fish and wildlife, recreation	344,800
Flaming Gorge Res.	Green R. (Utah, Wyo)	USBR	River regulation, power, recreation, fish and wildlife	3,749,000
Blue Mesa Res.	Gunnison R. (Colo.)	USBR	Water conservation, river regulation, power, recreation, fish and wildlife	829,500
Morrow Point Res.	Gunnison R. (Colo.)	USBR	Power	117,000
Crystal Dam & Res.	Gunnison R. (Colo.)	USBR	Reregulation of Morrow Point releases, power	17,600
Navajo Dam & Res.	San Juan R. (New Mex.)	USBR	Water conservation, flood control, recreation	1,696,400
Glen Canyon Dam, Lake Powell	Colorado R. (Ariz., Utah)	USBR	Power, recreation, fish and wildlife	25,002,000
Lower Basin				
Hoover Dam, Lake Mead	Colorado R. (Nev., Ariz.)	USBR	Flood control, water conservation, power, recreation fish and wildlife	27,377,000
Davis Dam, Lake Mohave	Colorado R. (Nev., Ariz.)	USBR	Reregulation, water conservation, power, recreation	1,810,000
Parker Dam, Lake Havasu	Colorado R. (Nev., Ariz.)	USBR	Forebay for MWD aqueduct power, flood control, river regulation, recreation	619,400
Alamo Dam and Res.	Bill Williams (Ariz.)	COE	Flood control, water conservation, and recreation	1,043,000
Painted Rock Dam and Res.	Gila (Ariz.)	COE	Flood control	2,491,700

Note: Some dams on lower basin tributaries are not included because of their limited effect on the Colorado River, which is due to distance from the main stem and relatively dry watersheds. Diversion dams providing little or no storage are not included.

The effects of the raised riverbed in Topock Gorge extended north to the City of Needles where a portion of the city became inundated. This emergency situation at Needles led to new legislation designed to deal with river problems along the entire lower river below Hoover Dam. Earlier authority under the Colorado River Front Work and Levee System Act was expanded in 1946 to permit the Bureau of Reclamation to initiate an active Lower Colorado River management program. Initially, the goal was to prevent flooding and destruction of lands resulting from meander of the river and deposition of sediment in the river channel. It soon became apparent, however, that other objectives needed to be incorporated in project plans. These included salvaging water, stabilizing and enhancing fish and wildlife habitats, and improving recreational opportunities. Appendix B describes in detail the channelization, levee construction, dredging, and related activities of the Bureau of Reclamation along the Lower Colorado River.

FLOOD HISTORY

Prior to construction of Hoover Dam, high flows along the Lower Colorado River occurred seasonally, and damaging flows were common. Floods occurred as a result of the snow melt runoff, large rainstorms in the upper basin, and rainfloods on the larger tributaries. The largest flood for which a historical record exists occurred in 1884. E. B. Debler, Bureau of Reclamation hydrologist, estimated that the peak flow of the 1884 flood at Black Canyon, site of Hoover Dam, was between 250,000 and 300,000 ft^3/s. Historical and modern records show that annual maximum peak flows at Black Canyon have probably exceeded 100,000 ft^3/s 31 times between 1878 and 1976; and during the same period, peak flows estimated in excess of 200,000 ft^3/s occurred 3 times.

Most early accounts concentrate on flood damages occurring in the Yuma area. Levee construction to provide protection from floods at Yuma was begun as early as 1902. Undoubtedly, the most dramatic incident related to early Colorado River floods was the 2-year fight during 1905 and 1906 to stop the flow of the river through an irrigation cut leading to the Alamo Canal and the Imperial Valley. Unusually high flows occurred on both the Gila and Colorado Rivers during this period; and at one time, the entire flow of the Colorado River was accidentally passing through the diversion. Ponding of the diverted flows in the Salton Sink formed the Salton Sea.

With the completion of Hoover Dam in 1935, control of most floods on the Colorado River to an outflow of 40,000 ft^3/s became possible. If a flood equal in magnitude to the 1884 flood were to occur again, it could be regulated sufficiently to reduce the peak inflow of about 300,000 ft^3/s to a peak outflow of 73,000 ft^3/s. Inflow records show that the floods of 1941, 1952, and 1957 were the largest floods that have occurred since the construction of Hoover Dam. In 1941 a maximum mean daily inflow of 119,200 ft^3/s was reduced to a maximum mean daily outflow of 35,500 ft^3/s. In 1952 the maximum mean daily inflow of 122,000 ft^3/s was reduced to a maximum mean daily outflow of 30,900

ft^3/s. In 1957 a maximum mean daily inflow of 124,000 ft^3/s was reduced to a maximum mean daily outflow of 18,400 ft^3/s. Each of these floods would have caused damage estimated at many millions of dollars to private property, public utilities, and flood-contol structures had Hoover Dam not been constructed.

FLOOD PROBLEM

Few, if any, structures were located in the 40,000 ft^3/s flood plain in the lower Colorado River at the time of the closure of Hoover Dam (1935) and for some years thereafter. For many years the flood control operation plan for Hoover Dam has incorporated a "target maximum" flood control release of 40,000 ft^3/s. A "target maximum" release is one that is not exceeded unless absolutely necessary. Encroachment of development into the flood plain in the last several decades has created a situation in which significant damages would now result from a release of 40,000 ft^3/s. Substantial damages in the Parker Strip would be caused by sustained release from Hoover Dam of over 28,000 ft^3/s. Several conditions have contributed to increased development in the Lower Colorado River flood plain: (1) lack of large flood control releases from Hoover Dam, (2) extensive growth in water-based recreation along the river, (3) lack of strong land use controls, and (4) encroachment of vegetation, especially in the Yuma area, which also reduces the flood-carrying capacity of the river.

Since the closure of Hoover Dam, flood-control releases in excess of 30,000 ft^3/s have been required five times: in 1939, 1941, 1942, 1952, and 1958. On only two occasions, 1941 and 1942, have these floods had sufficient volume to require sustained releases over 30,000 ft^3/s from Parker Dam. The construction of a system of reservoirs upstream from Hoover Dam during the period 1962 to 1966 has eliminated the need for flood control releases at Hoover in recent years. The upstream reservoir system has a combined storage capacity of over 33 million acre-feet. The largest single reservoir of the system is Lake Powell behind Glen Canyon Dam completed in 1963. Lake Powell has an active storage capacity of about 25 million acre-feet. Lake Powell did not completely fill until June 1980. Figure 1 shows a graph of maximum monthly flows since 1906 on the Colorado River below Hoover Dam. The graph illustrates both the dramatic effect of Hoover Dam on river flows and the further dampening effect of Lake Powell and the other upstream reservoirs.

Hoover Dam, along with Parker Dam, completed in 1938, has converted the once wild and violent Lower Colorado River into a domesticated and dependable stream with clean water and consistent size and depth in many locations. The river and its artificial lakes and wetlands have provided unique recreational and economic opportunities in a region otherwise hot, barren, and dry. Recreational users of the Lower Colorado come from nearby towns and farms and from as far away as Los Angeles, California, and Phoenix, Arizona, for boating, fishing, rafting, tubing, and camping. Many retirement developments have also

sprung up along the river to take advantage of the recreational opportunities as well as the warm, dry climate. Because the river is the main attraction of the area, recreational users, commercial developers, and retirees have tended to build their structures as close to the river as possible, making them vulnerable to the river at flood stage.

Many political entities, including Federal agencies, Indian tribes, states, counties, and cities have jurisdiction over land use of various segments along the Lower Colorado. For many reasons (apathy, ignorance of the potential problem, political and economic pressures, insufficient enforcement resources, and poorly defined authorities and rights), strong control over land use along the river has not been exercised in the past. More recent Federal, State, and local policies and programs are improving the management of flood-prone areas along the river. Executive Order 11988, Flood Plain Management, signed 24 May 1977, requires Federal agencies to provide leadership and to take action to:

a. Avoid usage of the base (100-year) flood plain unless it is the only practicable alternative.
b. Reduce the hazard and risk of flood loss.
c. Minimize the impact of floods on human safety, health and welfare.
d. And, restore and preserve the natural and beneficial flood plain values.

The provisions of Public Law 93-234 (Flood Disaster Protection Act of 1973) require communities, as a condition of future Federal assistance, to adopt zoning and land-use ordinances that control development of land subject to flooding. It also requires the purchase of flood insurance by property owners who are being assisted by Federal programs in the improvement of land or facilities located in flood hazard areas. Another important requirement of the Flood Disaster Protection Act is the expeditious identification and dissemination of information concerning flood-prone areas.

Arizona Revised Statute 45-2342 provides for the management of flood plains within Arizona by local flood plain boards. The local governing bodies are responsible for delineating flood plain areas. Arizona accepts flood hazard information developed by Federal agencies and endorses the use of these reports in delineating the flood plain areas.

Once the flood plain has been defined, the flood plain boards have the additional responsibility to adopt flood plain regulations governing construction within the flood plain. Among these are the prohibition of construction that may divert, retard, or obstruct floodwaters and the regulation that dwellings built within a flood plain shall be constructed to place the minimum floor elevation of the dwelling above the expected level of the 100-year-frequency flood.

The Bureau of Reclamation has been assigned the flood plain management responsibility for the lower Colorado River by the Boulder Canyon Project Act and the Colorado River Front Work and Levee System Act. The Bureau has actively carried out its responsibilities with respect to management of the river channel and its adjacent flood plain, as well as in the dissemination of flood hazard information to the public, within its authorities. The community awareness activities of the Bureau have included presentations to real estate organizations, chambers of commerce, and publication of flood plain maps and reports.

The Colorado River Front Work and Levee System is authorized by several acts, beginning as early as 1925. The most important act is that of June 28, 1946, which authorized appropriations to the Bureau of Reclamation for the purpose of:

1. Operating and maintaining the Colorado River Front Work and Levee System in Arizona, Nevada, and California;
2. Constructing, improving, extending, operating, and maintaining protection and drainage works and systems along the Colorado River;
3. Controlling said river, and improving, modifying, straightening, and rectifying its channel; and
4. Conducting investigations and studies in connection therewith.

Appendix B of this report describes Bureau of Reclamation river works along the Lower Colorado River.

As the Colorado River reservoir system fills (fig. 2), the flood potential along the river below Hoover Dam approaches conditions of the post-1935 period when flood releases from Hoover Dam in excess of 30,000 ft^3/s were more frequent. The U.S. Bureau of Reclamation maps 423-300-1412 through 1434, inclusive, and plates 2 through 7 show the outlines of areas that would be inundated by various sizes of floods. Flood frequency studies in which a repetition of historical flows was assumed show that, when the reservoir system is filled, there would be about a 10-percent chance in any given year for sustained releases averaging 28,000 ft^3/s or more for 1 month from Hoover Dam under the current operation plan.

Aside from some low-lying agricultural, recreational, and wildlife preserve areas, Parker Strip is the Lower Colorado River reach most vulnerable to flood damages. Damages would begin to occur with flows in excess of about 25,000 ft^3/s. (See pl. 3, sheets 1-4.) Property valued at nearly $800,000 would be susceptible to damage from a flow of 30,000 ft^3/s. Damages that would result from flow of 30,000 ft^3/s through Parker Strip are estimated at about $150,000. A flow of about 50,000 ft^3/s (about a 400- to 500-year flood) through Parker Strip would cause damages estimated at about $1.4 million to property valued at over $4.7 million. Types of property subject to damage in Parker Strip include residential, mobile homes, commercial, apartments and condominiums, recreational facilities, public property, and agricultural land.

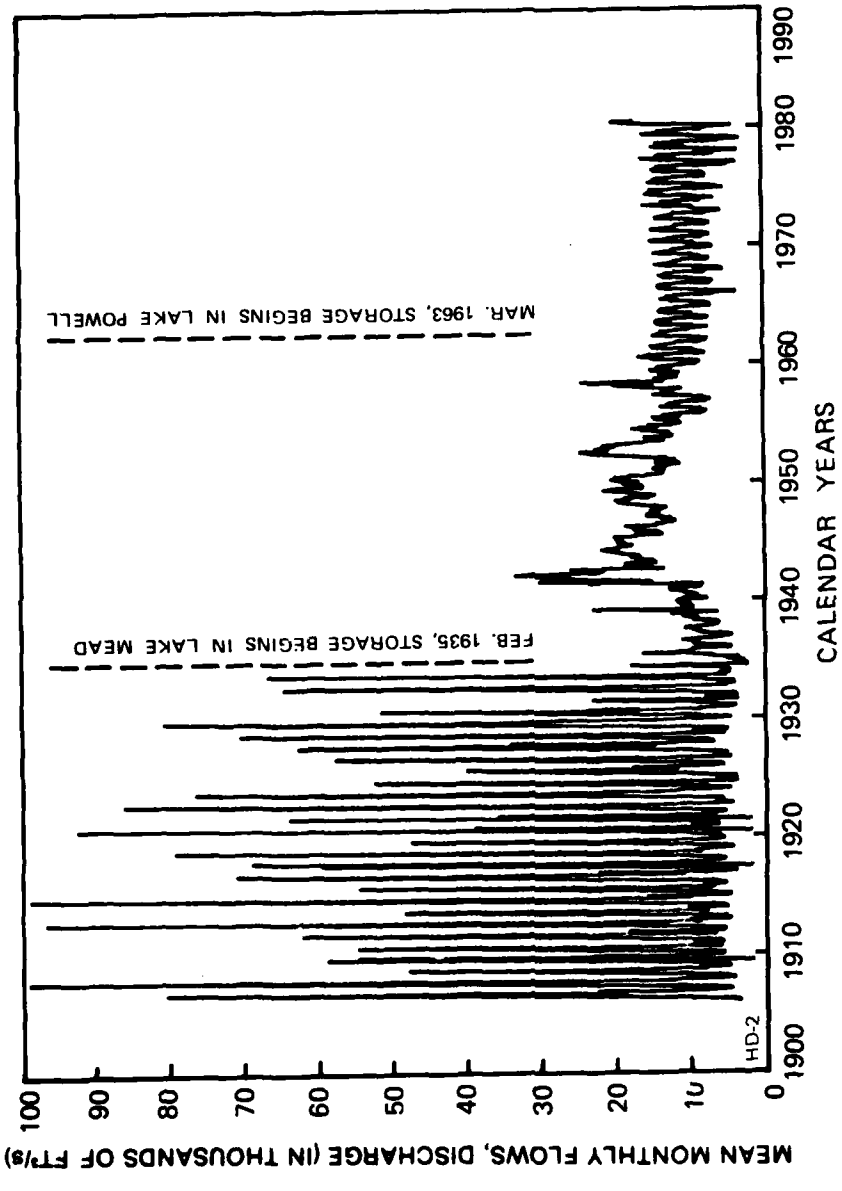


Figure 1. Mean monthly flows on the Colorado River below Hoover Dam.

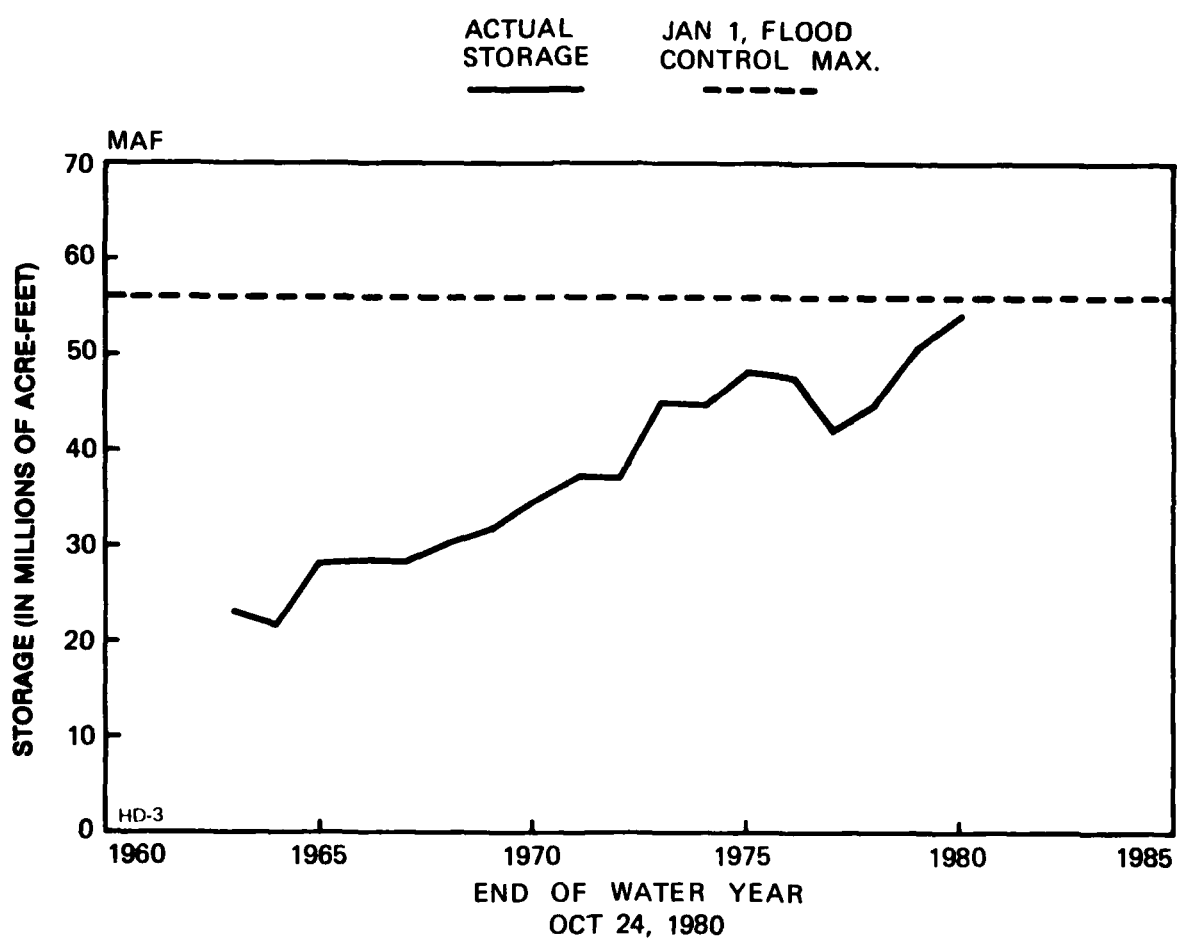


Figure 2. Colorado River reservoir system.

Flood damages at Needles would begin when flows exceed 30,000 ft^3/s. (See pl. 2.) A flow of 40,000 ft^3/s (about a 200-year flood under the current operation plan) would cause an estimated $10,000 damage to residential property on the east bank. Damages would increase rapidly for flows in excess of 40,000 ft^3/s. A flow of 50,000 ft^3/s would cause estimated damages of $41,000 to residential property and over $1.7 million to agricultural development.

Damages in the Blythe area solely from Hoover Dam releases would be rare under the current operation plan. Flood damages at Blythe would begin to occur when Colorado River flows exceed 38,000 ft^3/s. (See pl. 5.) The frequency of a flow at Blythe of 38,000 ft^3/s resulting from releases at Hoover Dam is about once in 300 to 400 years. Damages from a flow of 50,000 ft^3/s at Blythe are estimated at $199,000 to residential property and $22,000 to mobile homes. (The damage cost to mobile homes is the estimated cost of moving them to safety.)

The existing levees at Yuma are capable of containing flows up to nearly 140,000 ft^3/s. However, existing development located between the levees is vulnerable to damage from smaller flows. Some low-lying agricultural fields would be flooded at a flow of about 16,000 ft^3/s. A flow of 16,000 ft^3/s at Yuma resulting totally from Hoover Dam releases could be expected about once in every 3 to 4 years on the average. A flow of 40,000 ft^3/s would cause about $200,000 damage to about half a dozen farm structures between the Yuma levees. A flow of this magnitude resulting wholly from Hoover Dam releases would be quite rare--about once in 400 to 500 years under the current operation plan. A flow of 71,000 ft^3/s would flood all development between the Yuma levees, including about 54 structures, some of which are houses. It should be noted that, because of extensive growth of vegetation in the floodway at Yuma in recent years, the channel capacity between the existing levees has been reduced below the design value. A study is currently under way to assess the means of solving this problem.

The actual frequency of the flooding between the Yuma levees would be increased somewhat by flows from the Gila River. Infrequent flooding at Yuma can occur as a result of summer rainstorms centered on the Colorado River drainage area below Parker Dam or on the Gila River below Painted Rock Dam. Summer rainfloods in the Lower Colorado River Basin normally occur July through September and occasionally in June. Since Hoover Dam cannot be operated to compensate for rapidly rising rainflood peaks on the downstream watershed, there is a potential for rainflood peaks at Yuma adding to releases from Hoover Dam.

A somewhat greater possibility exists for flood control releases of flood runoff from Painted Rock Dam combining with snowmelt releases from Hoover Dam. Although no statistical studies have been made to determine the correlation between snowmelt floods on the Colorado and Gila Rivers, a correlation probably exists and probably increases with the size of event on the Colorado River. Most snowmelt floods on the Gila River can be controlled with peak flows not exceeding a few thousand ft^3/s at Yuma. However, Painted Rock Dam releases for floods in excess of the

50-year event could be as high as 22,500 ft^3/s. The largest floods on the Gila River above Painted Rock Reservoir would be generated by warm rain falling on snow. Except in very rare events, Hoover Dam could be operated to minimize the combined peak at Yuma for the following reasons: (1) The period for which large release would be required at Painted Rock is relatively short, about 8 to 10 days at 22,500 ft^3/s for the 100-year event; and (2) large releases from Painted Rock Dam are most likely to occur in the early spring, prior to mid-March, whereas large snowmelt releases from Hoover Dam are more likely to occur in late spring or summer.

The effect of Hoover Dam releases on the natural environment along the Lower Colorado River would be mixed. Sustained flows up to 20,000 ft^3/s would be predominantly beneficial to terrestrial and aquatic habitats from Davis Dam to Imperial Dam. As flows increase above 20,000 ft^3/s, potential for damage to terrestrial and aquatic habitats increases, especially through Topock Gorge, from Agness Wilson Road to Palo Verde Dam, and from Adobe Ruins to Imperial Dam. Flows above 30,000 ft^3/s would have some detrimental effects over the entire Davis Dam to Imperial Dam reach.

Below Imperial Dam, sustained flows up to 10,000 ft^3/s would be predominantly beneficial to terrestrial and aquatic habitats. As flows increase above 10,000 ft^3/s, the potential for damages to terrestrial and aquatic habitats increases along this reach. Because of the current channel conditions, the low past-flow regime, and proximity of vegetation to the river, the potential is high for some long-term loss of terrestrial habitats below Imperial Dam.

From an environmental standpoint, the time of year large releases from Hoover Dam occur is probably more important than the size of release. Large releases in the spring and summer would be the most detrimental because they would disrupt the nesting and breeding of most wildlife species and would cause inundation of plant communities during the growing season.

Endangered wildlife that might be disturbed by Hoover Dam releases are limited to a few bird and fish species. The Yuma clapper rail and peregrine falcon are the only endangered bird residents in the flood plain. Peregrine and prairie falcons are transient visitors to the Lower Colorado River Basin, and the bald eagle may visit there on rare occasions. The Colorado River squawfish and the woundfin, once native to the waters of the study area, are no longer found below Hoover Dam. The bonytail chub and the razorback sucker, designated as rare in California by the Department of Fish and Game, are occasionally found in the Lower Colorado River Basin. The bonytail chub is federally designated as endangered and is classified as Group II (in danger of being eliminated) in Arizona. Additionally, the razorback sucker is listed as Group III (a species whose status may be in jeopardy in the foreseeable future) in Arizona.

WATER SUPPLY--PRESENT AND PROJECTED NEEDS

The Colorado River Compact of 1922 divided the water between the upper and lower basins with the division point at Lee Ferry, in northern Arizona near the Utah border. The Compact also divided the states into an upper division, consisting of the states of Colorado, New Mexico, Utah, and Wyoming, and a lower division, consisting of the states of Arizona, California, and Nevada. Each basin was apportioned the right to beneficial consumptive use of 7.5 million acre-feet (MAF) per year from the Colorado River System. In addition, the lower basin was given the right to increase its use by 1 MAF per year. The Compact states that any required delivery of water to Mexico shall be supplied first from water surplus to the foregoing apportionments (a total of 16.0 MAF a year) and that, if the surplus is insufficient, the burden of the deficiency shall be borne equally by the upper and lower basins. It provides that the states of the upper division will not cause the flow at Lee Ferry to be depleted below 75 MAF for any period of 10 consecutive years.

In the Mexican Water Treaty of 1944, the United States agreed to deliver to Mexico a guaranteed 1.5 MAF annually from the Colorado River, with an additional 0.2 MAF per year to be delivered when there exists a surplus, as determined by the United States. In the event of extraordinary drought, Mexico's allotment is to be reduced in the same proportion that consumptive uses in the United States are reduced.

In addition to the Compact and the Treaty, apportionments of water in the Colorado River Basin are subject to many other documents, such as water supply contracts, Federal laws, and decrees of the U.S. Supreme Court.

At present, the Colorado River Basin has more than sufficient water to meet consumptive needs. Table 2 summarizes water uses for 1975. With present levels of use about 13 MAF from the main stream and an average annual flow above Hoover Dam of about 15 MAF, water storage should continue to accumulate in the system's reservoirs over the next decade. However, if future needs increase as projected, periodic shortages could occur in the future during periods following years of abnormally low runoff. The first water deliveries to the Central Arizona Project are projected for 1985, and the project should be capable of diverting a full water supply in 1986. Upper basin development is predicted to consume the remaining supply of Colorado River water by about the year 2040.

HYDROPOWER

Southern California Edison and Los Angeles Department of Water and Power operate the Hoover Dam power plant for the United States. Power is supplied to allottees in Arizona, California, and Nevada. The present name plate capacity is 1,340 megawatts but, because of the limited amount of water available, the Hoover power plant normally

operates at 32-percent capacity. In the future, the demand for Hoover energy is certain to increase. The population growth rate in cities in the Southwest is one of the fastest in the nation. Arizona and Nevada rank first and third, respectively, in the rate of population growth in the contiguous United States. Utility companies serving these areas must find additional sources to meet the electrical energy needs of this increasing population. The entities that utilize power from the Hoover power plant have indicated that they can use any and all additional energy that the plant can produce. Also, as supplies of nonrenewable fossil fuels decrease, the value of Hoover energy will increase.

WATER QUALITY

No large metropolitan centers are located along the Colorado River; therefore, the waters of the river show little degradation normally related to domestic, municipal, and industrial wastes. The mineral burden of the Colorado River is the foremost water quality problem in the basin. Waters of highly variable salt concentrations are introduced into the river in all reaches from various sources, and concentrations have increased with continuing development along the river until 1970. Since 1970 the quality of the water arriving at Imperial Dam has improved over the water that arrived before 1970. Improvement is expected to continue for the next several years for the following reasons:

1. Water supply presently exceeds demands because of delayed completion of projects currently under construction and delayed completion dates on authorized projects.

2. In the river reach between Parker Dam and Imperial Dam, as indicated by U.S. Geological Survey recorded data, irrigation diversions from 1974 through 1980 did not exceed 10 acre-feet per acre in the Parker Valley area; and return flows did not exceed 5.5 acre-feet per acre and averaged only 4.2 acre-feet per acre. In the 16-year period 1958 to 1973, return flows averaged 7.3 acre-feet per acre and exceeded 5.5 acre-feet per acre in each year. Diversions during this same period varied from over 10 to just under 16 acre-feet per acre. This is indicative of a reduction in the total salt returning to the river above Imperial Dam as well as a reduction in diversions from the river, thereby increasing the volume of better-quality water remaining in the river in the 7-year period 1974 to 1980.

3. The large volume of water in storage reservoirs since Lake Powell has filled tends to dampen the variations in total dissolved solids (TDS) concentrations during each year.

A further reduction in concentration of TDS at Imperial Dam could occur each time the reservoir system nears filling, causing surplus waters to be released into the river.

The records for 1971 to 1979 show that the concentration of TDS of the Colorado River at its headwaters was only 50 milligrams per liter (mg/l); the TDS at Imperial Dam increased to about 825 mg/l; and the TDS at the Mexican border was about 938 mg/l. Salinity concentrations for any 1 year, or part of a year, could have higher or lower values; and in some cases, the TDS at the Mexican border could be lower than that at Imperial Dam. This latter phenomenon occurs when high floodflows of better quality water (lower TDS) are contributed to the Colorado River by the larger downstream tributaries, such as the Gila River. TDS concentrations in any waters are increased by two means--an increase in the total salts in solution or a reduction in the solvent (in this case water). Usually salts in solution are increased by the pickup of salts from soils and any overlying or underlying strata as the water travels through or across these media. TDS concentrations, without the addition of salts, can occur as the result of the loss of water by evaporation, transpiration, and physical diversion. Studies indicate that about half of the TDS increase at Hoover Dam is caused by naturally occurring phenomena and the balance by man-induced activities. Major sources of increases in total dissolved solids in the waters of the Colorado River, listed in decreasing order of effect are: natural sources, irrigation, reservoir evaporation, out-of-basin export of water, and return from municipal and industrial uses.

Although the short-term trend of salinity concentration is currently downward, it is expected that the long-term trend will show increases in concentrations as Colorado River depletions increase. The passage of the Colorado River Basin Salinity Control Act (Public Law 93-320) authorized the Bureau of Reclamation to implement measures to control increases in salinity concentrations of the Colorado River System. These measures include:

- Point source control.
- Irrigation source control.
- Diffuse source control.

Point source control involves attempts to reduce accumulations to the Colorado River System of the natural occurring point sources of highly saline runoff at diverse locations throughout the basin. Identified point sources are: La Verkin Springs near Hurricane, Utah; Blue Springs near the confluence of the Little Colorado River and Colorado River; and the Lower Virgin River from its entrance to the Narrows above the Arizona-Utah State line to Lake Mead, near Las Vegas, Nevada. Irrigation source control involves attempts to reduce the diversions of excess water associated with the application of water to meet consumptive use requirements of irrigated lands and to reduce and/or control the timing of the occurrence of return flows from these lands. Identified irrigation areas that may be amenable to such controls are the Palo Verde Irrigation District and the Colorado River Indian

Reservation unit, among others. These measures would involve various attempts to control salinity concentrations at those levels suitable for the many and varied uses of the waters within the Colorado River Basin. This could include efforts in evaporation rate reduction. Status reports on La Verkin Springs and the Palo Verde Irrigation District were released in December 1979 and March 1980, respectively. A concluding report was issued in October 1979 on the Colorado River Indian Reservation unit.

Although increases in TDS levels are expected to have little adverse effect on instream uses such as recreation, hydroelectric power generation, and propagation of aquatic life, increased TDS concentration has and will cause economic losses in agricultural, municipal, and industrial operations. Agricultural losses arise from decreased crop yields, increased leaching requirements, increased management costs, and application of adaptive practices, such as crop patterns, improved drainage systems, and plantings on sloped beds. In municipal and industrial (M&I) operations, losses would result from increased water treatment costs, accelerated pipe corrosion and appliance wear, and increased use of soap and detergents. The Bureau of Reclamation has estimated damages resulting from projected increases in TDS levels in Colorado River water. The following tabulation (supplied by the Bureau of Reclamation) shows these annual damages at 10-year intervals in terms of 1980 dollars:

Year	(TDS in mg/1)	Salinity damages	Total direct Total damages
1980	*875	$126,137,750	$140,836,750
1990	1055	189,391,190	225,256,700
2000	1141	219,614,278	265,592,758
2010	1161	226,640,438	272,970,683

*Although 875 mg/1 does not reflect the actual 1980 salinity at Imperial Dam, this is the salinity expected, had average water supply conditions existed during this period.

These estimates were separately based on nondamaging or desired TDS levels of 500 mg/l for municipal and industrial water supplies and 750 mgl/1 for agricultural water supplies.

RECREATION

Millions of users of recreation indulge in a myriad of activities along the Colorado River each year. The river and its manmade lakes support water-based sports, such as swimming, boating, water skiing, sailing, fishing, and scuba diving. Other activities include camping, picnicking, hiking, motorcycling, off-road vehicle driving, and visits to points of interest, such as Indian petroglyphs. The Lower Colorado River recreational facilities attract visitors from as far away as Phoenix, Arizona, and the south coastal area of California. An annual winter influx of mobile retirees constitutes another large group of recreationists on the river.

Table 2. Summary of Colorado River System consumptive uses and losses by states, basins, and tributaries in 1975.

(1,000 Acre-feet)

State	Main stream		Tributaries (*)	Total (*)
	Upper basin	Lower basin		
Arizona	25	1,208	4,281	5,514
California	-	4,937	-	4,937
Colorado	1,778	-	-	1,778
Nevada	-	68	86	154
New Mexico	290	-	32	322
Utah	615	-	83	698
Wyoming	291	-	-	291
Subtotal	2,999	6,213	4,482	13,694
Main stream reservoir evaporation	607	1,158	-	1,765
Channel losses	-	322	-	322
Total in United States	3,606	7,693	4,482	15,781
Water passing to Mexico	-	1,656	-	1,656
TOTALS	3,606	9,349	4,482	17,437

Notes: a. Source of data was "Colorado River System Consumptive Uses and Losses Report 1971-1975," by the Bureau of Reclamation.

b. Total mainstream uses (upper plus lower basin) equal 12,955,000 acre-feet in 1975.

*Onsite consumptive uses and losses, includes water uses satisfied by groundwater overdraft.

Despite its already high level of use, the Lower Colorado River is still capable of supporting further recreational development and use, and recreational development can be expected to continue to grow. The economic contribution of the recreation industry is already important to the local economy along the river. This importance will grow proportionately with further exploitation of recreational opportunities.

Unfortunately, the existing recreational development along the river has been constructed in such a manner that not all of it is safe from large sustained flood releases from Hoover Dam. In the absence of more stringent controls on future development, the potential for flood damages to recreational development can be expected to increase.

COLORADO RIVER FLOODFLOWS IN MEXICO

The economic and social impacts of Colorado River floodflows in Mexico are considerable. The lack of floodflows in the Lower Colorado River in recent decades has led to utilizing the flood plain primarily for agriculture. Mexico, with approximately 500,000 acres of land under irrigation in the Mexicali Valley, has a big stake in preventing damage from the Colorado River floodflows.

Upon notification through the International Boundary and Water Commission that the filling of upstream reservoirs would cause a return to higher flows in the Lower Colorado River, the Mexican Government set about determining the extent of potential flooding in its territory and formulating plans to mitigate potential damages. On the basis of its findings, Mexico undertook a comprehensive flood protection program that included raising levees, removing channel constrictions, and building new levees and pump systems along the lower river. Further, a number of communities that had been near the river without protective works had to be relocated. According to Mexican authorities, the estimated cost of the flood protection improvements well exceeded $35 million.

Mexico's plans call for, and its levee system is being improved to provide, protection for essentially all the irrigated lands and communities in the Mexicali Valley against a river discharge of 28,000 ft^3/s. By September 1980, the works were largely complete. The plans also call for riprap protection of the levees in the threatened reaches, with this work performed early in 1981. Since a discharge of 28,000 ft^3/s has a return period of 140 years under the current operating plan, Mexico will have provided a high degree of protection to its developments in the Mexicali Valley with completion of the improvements. The only area not protected will be on the river side of the levees and the marginally developed lands near the mouth of the river that could not feasibly be protected.

Significantly, there appears to be little threat of flooding to Imperial Valley in California as a result of high floodflows on the Colorado River. Although flooding has occurred historically (most recently, from 1904 to 1907, during which time the present Salton Sea was created), combined factors make its recurrence unlikely: (1) The upstream section of the existing levees (the Ockerson levee) can handle 70,000 ft^3/s with freeboard down past a critical point on the Colorado River Delta at which point floodflows, if they were to break out, would pass southward into the Gulf of California rather than turn westward and northward into Imperial Valley; (2) Mexico's extensive irrigation network, consisting of canals with banks that are normally super-elevated, affords considerable obstruction to floodflows moving westward; and (3) through the operation of upstream reservoirs, a high degree of control of runoff exists that would permit floodfighting efforts to maintain control of the river against any westward diversion.

It is essential that the International Boundary and Water Commission continue its role of effecting close coordination between U.S. agencies responsible for upstream reservoir operation and the Mexican agencies responsible for the flood protective works in the Mexicali Valley before and during periods of high flows on the Lower Colorado River.

FORMULATION OF ALTERNATIVE PLANS

This section states the objectives of plan formulation, defines the criteria by which the alternative plans were formulated, describes the plans considered, and establishes evaluation criteria.

PLANNING OBJECTIVES

The primary purpose of the study leading to this report is to establish the best flood control operation plan for Hoover Dam. To this end, the following six water resource planning objectives were initially considered for plan formulation:

1. Flood damage reduction.
2. Water conservation.
3. Hydropower production.
4. Recreation.
5. Wildlife enhancement.
6. Water quality improvement.

In the early stages of plan formulation, the first three planning objectives (flood damage reduction, water conservation, and hydropower production) emerged as predominant because a reservoir-related flood control plan deals primarily with abnormally large flows and with storage volume. The latter three objectives (recreation, wildlife enhancement, and water quality improvement) are primarily functions of normal flow produced by day-to-day non-flood operations; therefore, this limited the formulation of alternatives to the first three objectives. The impacts of the alternatives on the latter three objectives, however, were considered in the evaluation of the alternatives.

Since the construction of Hoover Dam, the institutionalization of the Colorado River has grown steadily. Use of its water is now governed by a treaty with Mexico, two interstate compacts, water laws of seven states, numerous Federal statutes, court decrees, and water and power contracts. Some of the more important documents affecting the use of Colorado River waters are:

- Colorado River Compact - November 24, 1922.
- Boulder Canyon Project Act - December 21, 1928.
- Seven-Party Water Agreement - August 18, 1931.
- Boulder Canyon Project Water Contracts - April 24, 1930, through the present.
- Boulder Canyon Project Power Contracts - May 29, 1941, through the present.
- Boulder Canyon Project Adjustment Act - July 19, 1940.

- Mexican Water Treaty - February 3, 1944.
- Upper Colorado River Basin Compact - October 11, 1948.
- Colorado River Storage Project Act - April 11, 1956.
- General Principles to Govern, and Operating Criteria, for Glen Canyon Reservoir and Lake Mead During the Lake Powell Filling Period - April 2, 1962.
- Colorado River Storage project, General Power Marketing Criteria - 1962.
- Supreme Court Decree in Arizona v. California - March 9, 1964.
- Lake Mead Flood Control Regulations - July 29, 1968.
- Colorado River Basin Project Act (Public Law 90-537, 90th Congress, approved September 30, 1968).
- Criteria for Coordinated Long-Range Operation of Colorado River Reservoirs - June 10, 1970.
  State Water Laws.
- Contracts for sale of water from Colorado River Storage Project Reservoirs.
- Federal Water Pollution Control Act Amendments - 1972.
- Minute 242, Mexican Water Treaty - August 30, 1973.
- Colorado River Basin Salinity Control Act - 1974.

The degree of legal control exercised on the Colorado River serves to illustrate the economic importance of its water supply to an arid region and its energy-producing ability in an era of growing energy shortage. The importance of water supply and power required that the formulation of an array of flood control operation plans should be broad enough to achieve as full an exploitation of these assets as possible. To this end, alternative operation plans were formulated that, in turn, favored flood control, water supply, and power production.

PLANNING PERIOD

The period of most concern in this study is from the present until the Central Arizona Project (CAP) goes into operation, scheduled for 1985. CAP will divert water from Lake Havasu for consumptive use in Arizona. Expectations are that the amount of water diverted by CAP will be sufficient to largely eliminate surplus water in the Colorado River system, thereby reducing the probability of flood control releases from Hoover Dam and of damaging flows below the dam. Because CAP is expected to have a large impact on the flood control operation of Hoover Dam, the assumption has been made that the plan formulated in this study and report will be valid only until CAP becomes fully operational (about 1986). At that time the flood control operation will be reviewed again, and if necessary, a new plan will be formulated based on revised flood frequency projections. To allow for possible delays in fully completing all elements of CAP and to facilitate application of established computer models, a planning period of 10 years--from 1979 to 1989--was used for comparing theoretical damages and benefits under the various alternatives.

HOOVER DAM FLOOD CONTROL OPERATION

The Boulder Canyon Project Act of 1928 is the authorizing legislation for the construction of Hoover Dam. Section 6 of the act establishes flood control as one of the top priority purposes for the project as follows:

> Sec. 6. That dam and reservoir provided for by section 1 hereof shall be used: First, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and satisfaction of present perfected rights in pursuance of Article VIII of said Colorado River Compact; and third, for power * * *.

The function of Lake Mead and Hoover Dam in the control of floods is to capture and store enough flood volume so that flows downstream can be reduced to less-damaging, or even beneficial, size. To obtain the desired storage, a certain amount of storage space must be provided in Lake Mead (or upstream reservoirs) prior to each flood season. The effect of Hoover Dam on a particular flood is a function of the storage available at the time of the flood and the reservoir release pattern followed during the flood.

The flood control plan put forth in the "Report on Reservoir Regulation for Flood-Control Storage at Hoover Dam and Lake Mead," dated November 1968, is the basis for the development of alternative operating plans evaluated in this report. Hence, this section describes the 1968 plan, and subsequent sections explain the development of the alternative plans.

There are two different and distinct annual flood seasons on the Lower Colorado River: the late summer/early fall rainflood season and spring/summer snowmelt season. Any flood control operation plan for Hoover Dam must control both types of floods.

Summer/fall rainfloods normally have much smaller volume than snowmelt floods, but they can achieve quite large peaks. Previous studies have shown that, with 1.5 MAF of storage space available in Lake Mead, the standard project rainflood can be controlled to a maximum outflow of about 29,000 ft^3/s from Hoover Dam. The maximum inflow to Lake Mead during this flood would be about 120,000 ft^3/s. A standard project flood is defined as the flood resulting from the most severe combination of meteorological and hydrological conditions reasonably characteristic of the basin. The 1968 operation plan requires a minimum of 1.5 MAF to be provided in Lake Mead during the period 1 August through 1 October each year for control of summer/fall rainfloods. About 1.2 MAF of the required 1.5 MAF is actually surcharge storage above the top of the raised spillway gates. The 1.5 MAF, including surcharge, is the least allowable storage space in Lake Mead, except during actual flood operations. By controlling the standard project rainflood to a nearly nondamaging release from Hoover Dam, the 1.5 MAF requirement affords a high degree of protection but requires only a

small amount of dedicated Lake Mead storage space. Consequently, the 1.5 MAF requirement for 1 August was incorporated into all alternative plans considered in this report.

Controlling the typically large-volume snowmelt floods on the Colorado River requires much more storage space than controlling rainfloods. The annual virgin runoff from the drainage basin above Lake Mead is nearly 15 MAF, about 70 percent of which occurs during the spring and summer snowmelt season. The proper control of such large floods requires a judicious choice of available storage space and operating strategy so that benefits from the project may be realized to the fullest possible extent.

The 1968 operating plan requires releases from Lake Mead to be scheduled so that available space for flood control storage will not be less than indicated in the following tabulation for the dates shown.

Date	Available flood control storage space (acre-feet)
1 August	1,500,000
1 September	1,500,000
1 October	1,500,000
1 November	2,675,000
1 December	3,963,000
1 January	5,350,000

The available flood control storage space in Lake Mead on 1 November, 1 December, and 1 January could be reduced to a minimum of 1,500,000 acre-feet, provided the additional space prescribed in the above tabulation is available in active storage space in upstream reservoirs. The available storage space including surcharge storage is used to control releases to no greater than 40,000 ft^3/s insofar as possible.

The remainder of the 1968 flood control operation plan focuses on the control of forecasted reservoir inflow during the 1 January to 1 August snowmelt runoff period. The monthly runoff forecasts are maximum forecasts for any specified runoff period and are defined as the estimated volume (acre-feet) that, on the average, will not be exceeded 19 times out of 20. For the snowmelt runoff period from 1 January to 1 August, reservoir releases are based on (1) filling Lake Mead to the point where only 1,500,000 acre-feet of available storage remains on 1 August and (2) maintaining releases during that period to 40,000 ft^3/s or less, insofar as possible.

This discussion summarizes the key elements of the 1968 flood control operation plan as stated in the "Report on Reservoir Regulation for Flood-Control Storage at Hoover Dam and Lake Mead," dated November 1968.

FORMULATION CRITERIA AND ALTERNATIVE PLANS

Flood control storage behind Hoover Dam is only one of several ways of preventing flood damage along the lower Colorado River. Other methods might include channelization, levee construction, rights-of-way purchase, and land-use controls. The Bureau of Reclamation, through the Colorado River Front Work and Levee System along with Federal, State, and local regulations governing the use of flood plains, has already addressed these structural and nonstructural approaches.

Since the purpose and authority for this study relates specifically to the flood control operation of Hoover Dam and the alternative flood control methods are encompassed within other authorities, the formulation of alternative flood control plans was limited to the operation of Hoover Dam.

Of the wide range of possible combinations of storage space allocated to flood control and release strategy, nine were selected for evaluation. Each of these alternatives was formulated to favor, in turn, flood control, water conservation, and power generation.

As a starting point, a modified version of the 1968 flood control operation plan was designated alternative 1, and then used as a basis for comparing the other alternatives. The 1968 operating plan was not directly included as an alternative because knowledge of present damages and benefits of Hoover releases made adoption of certain changes to this flood control operation beneficial to any alternative. The 1968 plan was modified to limit space-building releases to a non-damaging level of 28,000 ft^3/s. This limit was imposed because a realistic operation would not permit damaging releases during a preparatory space-building period when no demonstrable flood threat exists. Also, the 1968 plan for controlling spring/summer snowmelt floods requires Lake Mead to be drawn down beginning 1 October so that 5.35 MAF storage space is available for flood control by 1 January. To help insure that 1 January storage space could be reached with a limit on space-building releases of 28,000 ft^3/s, the 1968 plan was modified to begin drawdown by 1 August, thereby extending the drawdown period by 2 months.

An additional significant difference between the 1968 operation plan and alternative 1 is in the manner releases are stepped up (increased) to control floods. Under the 1968 plan, the only objective was to control floods to 40,000 ft^3/s insofar as possible. Consideration of potential flood damages, water conservation benefits, and hydropower benefits occurring at lower releases made it necessary to incorporate five release steps into the operation. The five release steps are 19,000; 28,000; 35,000; 40,000; and 73,000 ft^3/s. Considering the forecasted inflow, releases during the period 1 January to 1 August are based on filling all available Lake Mead storage on 1 August, except for 1,500,000 acre-feet, while maintaining the lowest level (release step) of outflow. Stated differently, the average release in any month from 1 January to 1 August is determined by solving the following equation:

Volume of water released in the current month

+ volume of water to be released at the lowest appropriate step for the remaining months through 1 August

+ available storage space to top of flood control pool

- 1,500,000 acre-feet must

= the forecasted inflow volume through 1 August.

Should water-use requirements be greater in the current month than the required flood control release, releases would be made to satisfy water-use requirements. The release-selection process is repeated each month to reflect a revised forecast and available storage space. As in the 1968 plan, the monthly runoff forecasts are maximum forecasts for the remainder of the runoff period and are defined as the estimated volume (acre-feet) that, on the average, will not be exceeded 19 times out of 20.

The step releases used in alternative 1 are based on the following considerations. The lowest step, 19,000 ft^3/s, is based on the power plant capacity of Parker Dam. Releases in excess of 19,000 ft^3/s for periods beyond the limited modulating capacity of Lake Mohave and Lake Havasu would waste energy by bypassing the Parker power plant. The next step, 28,000 ft^3/s, is the approximate maximum release at Hoover Dam that will not cause damage through Parker Strip. Also, the power-plant capacity at Davis Dam is 28,000 ft^3/s. The power plant capacity at Hoover Dam is approximately 35,000 ft^3/s, which establishes the third step. At the time Hoover Dam was completed, 40,000 ft^3/s was the approximate maximum nondamaging flow downstream from the dam, and the dam was designed to operate to not exceed this release, if at all possible. Releases of 40,000 ft^3/s and greater are necessary to control large floods. The fifth and last step in the series, 73,000 ft^3/s, is the approximate maximum controlled release from the outlet works at Hoover Dam.

With the modified 1968 operating plan established as alternative 1, the next step in plan formulation was to develop a broad array of alternatives combining various storage space requirements with various operating strategies and to include in the array those alternatives that would, in turn, favor flood control, water conservation, and power generation. The 1 August 1.5 MAF storage space requirement, the extension of the space-building period to August through December, the 28,000 ft^3/s upper limit on space-building releases, and the variations of the five-step release strategy used in alternative 1 were all incorporated into all alternatives.

Two alternatives (2 and 4) were formulated to stress two different approaches to flood control. Alternative 2 was formulated by determining the storage space required on 1 January each year that would have produced the smallest maximum monthly peak outflow from Hoover Dam through the 72-year period of record. The calculation resulted in a plan having 5.67 MAF of storage space, which would have controlled floods experienced through the period of the historical record with a maximum 1-month outflow of 33,600 ft^3/s. Either more or less than 5.67 MAF of 1 January storage space would have resulted in releases greater than 33,600 ft^3/s for at least 1 month during the 72-year period. With less than 5.67 MAF of 1 January storage, spring flood releases greater than 33,600 ft^3/s are necessary. Similarly, with more than 5.67 MAF of 1 January storage, fall space building releases greater than 33,600 ft^3/s are required. It is significant that 33,600 ft^3/s is the minimum required release to control the historical record regardless of the choice of 1 January available storage requirement. The same step release operating strategy that was used for alternative 1 was used for alternative 2.

The flood control concept behind the formulation of alternative 4 was to not make releases in excess of the estimated nondamaging release. This alternative calls for 5.35 MAF of storage space on 1 January, the same as alternative 1, but it has only two release steps, 19,000 and 28,000 ft^3/s. Floods that could not be controlled with the maximum 28,000 ft^3/s release would flow over the spillway.

The maximization of water conservation in Lake Mead requires that releases from Hoover Dam be limited to consumptive needs to the extent possible. Intuitively, the most effective way to eliminate releases in excess of needs is to reduce the amount of storage space required for flood control at the beginning of each flood season. (Benefit calculations showed this assumption to be invalid.) In an attempt to formulate alternative plans favoring water conservation, minimum reasonable storage space requirements for flood control were determined. Because 1.5 MAF in Lake Mead will control the summer rainflood to a near nondamaging release, this amount of space was selected as a starting point. The operating criteria for Glen Canyon Dam require no flood control space in Lake Powell at any time. However, the long-range operating strategy for power production at Glen Canyon Dam requires that spills be avoided; and in order to avoid spills at Glen Canyon Dam, some evacuation of Lake Powell would be required prior to the spring flood season. Estimates by the Bureau of Reclamation indicate that at least 3.0 MAF of storage space would be available in the upper basin reservoirs each spring. For the formulation of plans favoring water conservation, the minimum January storage-space requirement was taken as 4.5 MAF, the sum of the 1.5 MAF required in Lake Mead to control the summer rainflood, and the 3.0 MAF probably available each spring in Lake Powell.

It is recognized that it could be possible that the flood control alternatives investigated might necessitate release from Lake Powell in order to equalize storage on September 30, but such would occur only under very unlikely circumstances. Prior to August 1, Lake Powell and all other Upper Basin reservoirs would have had to have filled to capacity, and Lake Mead would have had to have filled except for 1.5 million acre-feet (MAF) of required flood control space. Even so, there would still be no possible effect on Lake Powell's operation due to space building requirements unless its contents exceed 24.669 MAF during September. This remaining conservation space in Lake Powell would amount to 0.333 MAF at that level of storage. Typical operation of Lake Powell during the months of August and September would probably preclude the possibility of the reservoir being that full by the end of September, even if the runoff from previous months had filled it to capacity before August 1. Scheduled releases from Lake Powell for power generation during August and September under these conditions would probably exceed normal inflow by an amount greater than the maximum of 0.333 MAF which could be forced out by the Long-Range Operating Criteria provision to equalize storage in Lakes Powell and Mead. It is also likely that operation of Flaming Gorge, Blue Mesa, and Navajo reservoirs during these 2 months would create additional creditable flood control space. This would further diminish the likelihood of a storage split being forced by space building releases from Lake Mead.

Alternatives 3, 6, and 7 were formulated to favor water conservation. The effect of different operating strategies was tested by varying the release steps in these three plans. Release steps of 19,000; 28,000; 35,000; 45,000; and 73,000 ft^3/s were used with alternative 3. Steps of 19,000; 28,000; and 40,000 ft^3/s were used in alternative 6. Alternative 7 has release steps of 19,000; 28,000; 35,000; 40,000; and 50,000 ft^3/s.

The maximization of hydropower generation requires that releases in excess of power-plant capacity be avoided insofar as possible. Alternative 5 was formulated with a maximum controlled release of 35,000 ft^3/s, maximum power-plant capacity at Hoover Dam. Rare floods requiring releases greater than 35,000 ft^3/s would overflow the spillway under the operation defined by alternative 5. The plan includes a 1 January storage of 5.35 MAF. Alternative 8 calls for a large 1 January storage of 7.5 MAF for the purpose of minimizing any bypassing of power plants.

To further test the effect of different release strategies, alternatives 5 and 9 were added. These alternatives require 5.35 MAF of storage space on 1 January as do alternatives 1 and 4; however, they differ in release strategies. Alternative 5 calls for release steps of 19,000; 28,000; and 35,000 ft^3/s. Alternative 9 includes release steps of 19,000; 28,000; 35,000; 50,000; and 73,000 ft^3/s. Table 3 summarizes the alternative plans with their storage requirements, release steps, and other information.

Table 3. Alternative plans.

Alternative	1 January storage (MAF)	Maximum controlled release	Formulated to favor	Release steps (1,000 ft^3/s)
1	5.35	73,000	Bal.	19, 28, 35, 40, 73
2	5.67	73,000	FC	19, 28, 35, 40, 73
3	4.50	73,000	WC	19, 22, 35, 45, 73
4	5.35	28,000	FC	19, 28
5	5.35	35,000	P	19, 28, 35
6	4.50	40,000	WC	19, 28, 35, 40
7	4.50	50,000	WC	19, 28, 35, 40, 50
8	7.50	73,000	P	19, 28, 35, 40, 73
9	5.35	73,000	FC & P	19, 28, 35, 50, 73

Notes:
1. All alternatives require 1.5 MAF storage space on 1 August.
2. Space-building operations begin on 1 August for all alternatives.
3. Bal. denotes balanced; FC, flood control; WC, water conservation; P, power.
4. Results of analysis may not agree with the formulation objective.

EVALUATION CRITERIA

The Water Resources Council's (WRC) Principles and Standards for Planning Water and Related Land Resources require that Federal actions relating to water resources be evaluated for their effects on national economic development, environmental quality, social well-being, and regional development. The alternatives studied in this report were all evaluated for the WRC criteria and their impacts are discussed under the heading "Assessment and Evaluation of Alternatives."

Specific contributions to national economic development for this study might include benefits from reduction in flood damages, increased water conservation, increased hydropower generation, improved water quality, and increased recreational opportunities. Impacts of the various alternatives on environmental quality could include changes in water quality (particularly, changes in salinity), and positive and negative effects of changes in frequency of flooding on wildlife and wildlife habitat. Effects on regional development are local economic effects that generally parallel the effects on national economic development. Effects on social well-being include such intangible impacts as reduction in the threat of personal financial losses or physical harm. Reduction in flood damages or the threat of flood damages can improve social well-being in a community by reducing the amount of local resources required for flood fighting and recovery from flood damages. The resources thus conserved can then be used to provide positive contributions to quality of life in the community. In addition, consideration was given to the effects of flood discharges along the Mexican portion of the river.

To facilitate a fair and equitable comparison of alternative plans, a common basis for comparison is needed. Normally, in the case of a project requiring new construction, project alternatives are compared to a "without project" condition. For this study, the basis used for comparing alternative plans was alternative 1, a modified version of the 1968 flood control operation plan.

ASSESSMENT AND EVALUATION OF ALTERNATIVES

This section identifies, describes, and where possible, quantifies the predicted impacts of the alternative plans.

PREDICTED IMPACTS

All plans were compared against alternative 1, a modified version of the current operation plan. The basis for selecting alternative 1 for comparison was that it retained the same 1 January and 1 August flood control storage space requirements as the 1968 flood control plan. Understanding the differences among the alternatives can be enhanced by realizing that the only operational differences are the timing and size of Hoover Dam flood control releases, and the differences in releases are caused by variations in one or both of two operational criteria: (1) requirement of 1 January flood control storage space, and (2) step release pattern. Table 4 lists the operational criteria in which the alternative plans differ, and also gives the economic impacts of the alternatives in absolute value terms. Table 5 compares the relative impacts of alternatives 2 through 9 with those of alternative 1. None of the alternatives requires capital investment.

The following paragraphs point out the more salient differences of the plans. Unless otherwise stated, all costs and benefits are equivalent annual values. The basis for the dollar valuations of each economic category is described in appendix C. Estimates of plan benefits and damages were based on July 1978 price levels.

Alternative 2

The only operational difference between this plan and alternative 1 is an increase in the storage space required on 1 January from 5.35 to 5.67 MAF. The largest economic impact of the increased storage space requirement would be in water conservation. After 10 years of operation under alternative 2, Lake Mead would contain 43,000 acre-feet less water in storage than it would under alternative 1. (See table 4.) The average annual reduction in the value of stored water would be $93,000 (table 5). About two-thirds of the loss would be offset by increased diversions to Los Angeles Metropolitan Water District (MWD) during the 10-year period. The net average annual loss in water conservation would $33,000. There would be a net increase in hydropower generated of 2 million kilowatt hours (mkwh) having a value of $60,000 annually. Plan 2 would result in a small improvement in flood control, $13,000 average annual, and no increase in salinity. Operation and maintenance costs would be $7,000 a year higher under alternative 2 than under alternative 1. Alternative 2 is estimated to produce average annual net benefits of $33,000 in excess of alternative 1.

Alternative 3

The required 1 January storage space for this plan was reduced to 4.50 MAF, an amount that approaches a practical minimum, in an attempt to maximize the amount of water stored in Lake Mead each year. Plan 3 also incorporates a change in release steps by replacing the 40,000 ft^3/s step with a 45,000-ft^3/s step. The reduced 1 January storage space would result in an increase in the amount of water stored in Lake Mead at the end of the planning period. However, net water conservation benefits would decrease substantially ($108,000 per year) under this plan because of a decrease in MWD diversions. There would be a net reduction in hydropower generation of 2 mkwh having a value of $60,000 annually. Flood damages would decrease about 12 percent, about $19,000 on an average annual basis, compared with plan 1. The plan would cause no increase in salinity, and operation and maintenance costs would average about $7,000 a year higher than for alternative 1. Average annual net benefits would be $156,000 smaller than alternative 1.

Alternative 4

This plan would have the same storage space requirements as alternative 1, but controlled releases would be limited to 28,000 ft^3/s. The purpose of the plan is to demonstrate the effects of operating with controlled releases limited to the estimated nondamaging release or less. Floods too great to be controlled with a maximum 28,000 ft^3/s release would cause spillway overflow. Except for water in storage at the end of the planning period, which would be the same as for alternative 1, alternative 4 would perform more poorly in all economic outputs. The plan would be particularly poor in flood control--the motivation responsible for the plan. Flood damages under alternative 4 would be about 2.1 times the flood damages under alternative 1. Net average annual economic benefits from all sources would be $626,000 less under alternative 4 than under alternative 1.

Alternative 5

The purpose of this plan is to demonstrate the effects of limiting controlled Hoover Dam releases to Hoover power-plant capacity. The plan calls for the same storage-space requirements as alternative 1, but the maximum controlled release would be limited to 35,000 ft^3/s. The plan is the same as alternative 4 except for the addition of the 35,000 ft^3/s release step. The economic impacts of alternative 5 would be much better than alternative 4, but they would not be as good as alternative 1 in three respects: (1) Water in storage at the end of 10 years of operation would be 26,000 acre-feet less than under alternative 1; (2) flood damages during the period would be about $39,000 higher on an average annual basis; and (3) operation and maintenance costs would average about $16,000 a year more. Salinity costs, hydropower, and MWD diversions would be the same under alternatives 1 and 5. Average annual net benefits would be $111,000 less than alternative 1.

Item	1	2	
		Plan description	
1. January 1 storage (MAF)	5.35	5.67	
2. Max. controlled release ($1{,}000$ ft^3/s)	73	73	
3. Release steps ($1{,}000$ ft^3/s)	19,28,35, 40,73	19,28,35, 40,73	19
		Average annual economic valu	
Hydropower (mkwh) ($0.03 per kwh)	12,252	12,254	
Water ($1{,}000$ a-f)			
Lake Mead ending storage* ($30/a-f)	20,213	20,170	
MWD diversions ($30/a-f)	921	923	
Flood damages ($1,000)	150	137	
Salinity (p/m) ($293,400 per p/m)	715	715	
Operation and maintenance ($1,000)	2,194	2,201	

Note: *mkwh = million kilowatt hours; a-f = acre-feet; and p/m = parts per million.*
*Ending values for period of record analysis rather than average annual values.

Item	1	2	
		Plan description	
1. January 1 storage (MAF)	5.35	5.67	
2. Max. controlled release ($1{,}000$ ft^3/s)	73	73	
3. Release steps ($1{,}000$ ft^3/s)	19,28,35, 40,73	19,28,35, 40,73	1
		Relative economic impacts (equ	
Hydropower	-	60	
Water			
Lake Mead ending storage	-	-93	
MWD diversions	-	60	
Flood damages	-	13	
Salinity	-	0	
Operation and maintenance	-	-7	
Relative net benefits	-	33	

Note: The values given in this table represent the relative difference from alternative 1. benefits afforded by the plan.

Table 4. Economic comparison of alternative plans.

Alternative							
2	3	4	5	6	7	8	9
lan description							
5.67	4.50	5.35	5.35	4.50	4.50	7.50	5.35
73	73	28	35	40	50	73	73
19,28,35, 40,73	19,28,35, 45,73	19,28 35	19,28, 35,40	19,28, 40,50	19,28,35, 40,73	19,28,35, 50,73	19,28,35,
nnual economic values for each Alternative							
12,254	12,250	12,248	12,252	12,250	12,250	12,254	12,252
20,170	20,218	20,213	20,187	20,218	20,218	19,702	20,213
923	917	920	921	917	917	921	921
137	131	321	189	165	142	111	136
715	715	716	715	715	715	714	715
2,201	2,201	2,206	2,210	2,208	2,208	2,211	2,210

r million.
l values.

Table 5. Economic comparison of alternative plans with Plan 1.

Alternative							
2	3	4	5	6	7	8	9
lan description							
5.67	4.50	5.35	5.35	4.50	4.50	7.50	5.35
73	73	28	35	40	50	73	73
19,28,35, 40,73	19,28,35, 45,73	19,28, 35	19,28, 35,40	19,28, 40,50	19,28,35, 40,73	19,28,35, 50,73	19,28,35,
nomic impacts (equivalent annual values in thousands of dollars)							
60	-60	-120	0	-60	-60	60	0
-93	12	0	-56	12	12	-1,115	0
60	-120	-30	0	-120	-120	0	0
13	19	-171	-39	-15	8	39	14
0	0	-293	0	-0	-0	293	0
-7	-7	-12	-16	-14	-14	-17	-16
33	-156	-626	-111	-197	-174	-740	-2

om alternative 1. Minus indicates a decrease in relative

Alternative 6

This plan requires 4.50 MAF of storage space on 1 January and has release steps of 19,000; 28,000; 35,000; and 40,000 ft^3/s. The greatest economic impact of alternative 6 compared with alternative 1 is a reduction in MWD diversions of about 4,000 acre-feet per year with an annual value of $120,000. Flood control under alternative 6 would be slightly less effective than under alternative 1; flood damages would average about $15,000 a year more. Ending storage would be improved slightly by about 5,000 acre-feet. Hydropower generation would be 2 mkwh less than under alternative 1. Operation and maintenance costs would be about $14,000 a year higher than for alternative 1. Average annual net benefits under alternative 6 would be $197,000 less than under alternative 1.

Alternative 7

Alternative 7 is the same as alternative 6 except that an additional release step of 50,000 ft^3/s has been added as the maximum controlled release. The overall economic impacts would also be the same as alternative 6 except for flood control, which would be slightly less effective under alternative 7. Average annual net benefits would be $174,000 less than alternative 1.

Alternative 8

The purpose of this plan is to demonstrate the effect of providing a relatively large 1 January storage space each year. The plan calls for 7.50 MAF to be provided each January. Step releases are the same as those used in alternative 1. Alternative 8 would out-perform alternative 1 in preventing flood damages by about $39,000 on an average annual basis. Annual hydropower production would also be increased by 2 million kilowatt hours. The plan would also improve salinity. The large 1 January storage requirement would exact a high price in stored water to gain its advantages in flood protection and improved salinity. At the end of the 10-year study period, Lake Mead would contain about 511,000 acre-feet less water in storage than under alternative 1. The plan would not enable an increase in diversions to MWD, so the entire reduction in storage would be lost to the Gulf of California. The average annual value of water lost would be $1,115,000. Alternative 8 would also have the highest operation and maintenance costs by a small margin over alternatives 5, 6, 7, and 9 and by about $17,000 over alternative 1. Net annual benefits for alternative 8 would be about $740,000 less than for alternative 1. The environmental analysis for the study concluded that the environmental differences among the nine alternatives studied would not be significant. However, alternative 8 would have a small environmental superiority based on certain comparisons. Based on peak average monthly flows, alternative 8 would have an advantage over the other plans because monthly peaks for floods greater than the 20-year (5-percent chance) flood would be lower under this alternative. At least some of the advantage of lower peaks would be lost because of greater duration

of these peak flows which would also be of environmental importance. A more significant environmental advantage of alternative 8 would be its high 1 January storage requirement, which would tend to shift peak flows to the August-through-December space-building period, thus reducing the likelihood of peak flows during the environmentally sensitive spring and early summer period.

Alternative 9

The only difference between this plan and alternative 1 is a change in one of the step releases from 40,000 to 50,000 ft^3/s. The economic impacts of alternative 9 would also be the same as those of alternative 1 except for a small improvement ($14,000 average annual) in flood control and an increase of $16,000 a year in average annual operation and maintenance costs. Net economic benefits from all sources would be about the same for alternatives 1 and 9.

SOCIAL IMPACTS

Differences in social impacts among the nine alternatives are difficult to discern. Social impacts to be considered might include injury, death, displacement from one's home, and the emotional trauma of heavy individual financial losses. Social impacts normally correlate well with the number of inhabited structures and public-use structures subject to flooding. Along the Lower Colorado River, the Parker Strip reach contains the most inhabited and public-use structures with the greatest vulnerability to flooding, and, therefore, would endure the majority of the social impacts from flooding. Table 6 shows the number of structures in the Parker Strip reach subject to flooding by flows of 30,000 and 40,000 ft^3/s. Depths of flooding for these flows would range up to 4 and 6 feet, respectively.

Table 6. Number of structures subject to flooding in Parker Strip.

Type	Number of structures affected by flow of 30,000 Ft^3/s	40,000 Ft^3/s
Residential	34	46
Mobile homes	17	90
Commercial	1	5
Semipublic	0	6
Total	52	147

One measure for comparing the social impacts of the alternative plans is the frequency with which structures would be flooded. Table 7 lists by alternative the frequency of 30,000- and 40,000-ft^3/s flows resulting solely from Hoover Dam releases.

Table 7. Number of times in 100 years that flows resulting solely from Hoover Dam releases would be equaled or exceeded through Parker Strip.

Flow (ft^3/s)	Alternative plan								
	1	2	3	4	5	6	7	8	9
30,000	4.0	4.0	4.0	0.90	4.0	4.0	4.0	0.8	4.0
40,000	0.32	0.30	0.60	0.71	0.59	0.49	0.56	Less than 0.1	0.58

Based on the frequency of flooding of structures in Parker Strip, alternative 4 would have an advantage at 30,000 ft^3/s, but carries a greater risk of larger floods than all the other alternatives. Alternative 8 has a definite frequency of occurrence advantage at 30,000 ft^3/s and maintains the advantage for larger flows. One disadvantage of alternative 8 not disclosed by the frequency analysis would be greater duration of high flows and larger nonpeak flows. These characteristics would have some negative social impacts, particularly in displacement from homes. Many of the Parker Strip homes are secondary or vacation residences, which would somewhat soften the impact of displacement. Because the social impacts through the Parker Strip are indicative of the impacts through all developed reaches, the analysis can be considered representative of all reaches.

Sufficient warning time would be available with all alternatives to prevent injury or death resulting from unexpected flood waves. Any time larger- and faster-than-normal flows occur, however, a possibility for accidents exists. Injury and death resulting from careless or reckless behavior or during flood-fight operations can occur. All nine alternatives pose this threat. None of the plans has any obvious advantage in safety.

Social impacts could also result from shortages of water and hydropower. The impacts of most of the alternatives, however, would be mainly in the nature of inconveniences caused by conservation measures requiring reduced uses of these resources for luxury purposes. Alternative 8 could, under extreme drought conditions, result in somewhat more serious water shortages.

DIVISION OF RESPONSIBILITIES

Responsibility for implementing the selected flood control operating plan would be the same under all alternatives, and would rest primarily with the Federal Government through the Bureau of Reclamation and the Corps of Engineers. These two agencies would be responsible for preparing appropriate regulation manuals and other working documents. At the time of actual flood control operation, the Corps of Engineers would have the ultimate decision-making responsibility, which would be

exercised only after consultation with the Bureau of Reclamation in particular, and other concerned agencies, including the U.S Section, International Boundary and Water Commission. The Bureau of Reclamation would be responsible for the physical operation of Hoover Dam, and also for the operation and maintenance of channels and levees along the Lower Colorado River, as well as for emergency flood-fighting operations should the need arise. Local governmental agencies, the Bureau of Indian Affairs, and the Bureau of Land Management would have no direct responsibility for implementing the selected plan. These agencies would have indirect responsibilities for (1) providing both emergency and non-emergency information to the Bureau of Reclamation and the Corps of Engineers; (2) discouraging inappropriate development in the flood plain within their jurisdictions; and (3) providing flood warning, flood fighting, and other emergency actions within their jurisdiction.

PUBLIC INVOLVEMENT

The following section details public involvement in the preparation of this report.

Public Meeting Viewpoints

Prior to preparation of a draft report on the study, public involvement was initiated through work-group meetings and a series of six public meetings (April and May 1979) to obtain the views of non-Federal agencies and private interests. A brochure, titled "Study for Reevaluation of Hoover Dam Flood Control Regulations," which summarized study objectives, alternatives considered, and findings, was distributed to all meeting participants. As expected, the views, although accompanied by expressions for reasonable compromise, corresponded to the vested interests of the respondents.

Of all the groups that could be affected by flood control releases from Hoover Dam, property owners along the river are the most directly threatened. This group expressed its concerns in several different ways, particularly at the Needles and Parker public meetings, but they can be summarized as a desire to limit flood releases to a nondamaging level. Additionally, riparian property owners and others engaged in daily activities along the river showed concern over the large daily fluctuations in flows. A desire was expressed that the smaller daily flows be increased in size by using flood control releases to smooth the daily fluctuations.

Several agricultural water users' organizations responded to the study, both in writing and with oral statements at the public meetings. In general, the water districts recognized the potential need for flood control releases, but expressed concern that Lake Mead should not be so depleted that agricultural water supplies would be threatened by several consecutive drought years.

At the Los Angeles public meeting, the Metropolitan Water District (MWD) contended through a prepared statement that the economic benefits to be gained from water conservation and hydropower production by maintaining only minimal flood control storage space in Lake Mead would far outweigh potential flood damages. The District suggested that 1 January Lake Mead storage could be reduced to 4.10 MAF, and the flood problem could be resolved by flood plain zoning, relocation, and other methods to provide a minimum channel capacity of 35,000 ft^3/s downstream from Hoover Dam. The MWD believes that the cost of providing additional channel capacity would be justified by increased water and power benefits. The District disagreed with the unit costs used in the study for water and power benefits and suggested that $150 per acre-foot and 40 mils per kilowatt-hour would be more appropriate. A letter received from the Central Basin Municipal Water District of Downey, California, expressed support for MWD's position.

In a letter responding to the public meeting notice, the California Department of Water Resources expressed the intent to work with MWD and the Colorado River Board of California to develop "* * * means of putting to beneficial use those waters that otherwise would be in excess of Lower Basin water demands and storage capacity." The Department also urged the use of flood-plain-management measures, such as the purchase of rights-of-way and land-use controls, to reduce future flood hazard along the Lower Colorado River.

The Colorado River Board represents California in exercising the State's rights and interests in the Colorado River. Because the Board represents all California citizens, it has an interest in all facets of the river's operation. The Board, however, considers the major benefit to California to be water for agricultural and municipal and industrial uses. The Board urges that strong weighting be given to maintaining Lake Mead as full as possible while, at the same time, providing protection against flooding. The Board recommended the selection of either alternative 1 or alternative 9 as the best compromise among all project purposes.

The Arizona Department of Water Resources (ADWR) is a broad-based agency responsible for water resources planning in Arizona. Protection of Arizona's rights and interests in Colorado River waters is one of the duties of the ADWR. The ADWR urged the selection of either alternative 1 or alternative 9 as the recommended flood control operation plan for Hoover Dam.

As a result of the public meeting, three formal responses addressing environmental issues have been made. Letters have been received from the Maricopa Audubon Society, the Arizona Game and Fish Department, and the California Department of Fish and Game.

The Audubon Society comments stressed protection of the endangered Yuma Clapper Rail and urged that releases greater than 20,000 ft^3/s be prohibited in the February-through-April period. The Society's concern is that greater releases during the early spring would flood nests, eggs, and riparian vegetation needed for cover.

The Arizona Game and Fish Department recognizes the potential for environmental damages resulting from Hoover flood control releases. The Department agrees with the concept that some environmental benefits may also result from flood releases.

The California Department of Fish and Game favors new regulations for operating Hoover Dam that would result in higher winter flows on the Lower Colorado River. The Department believes a continuous flow of about 4,000 ft^3/s would provide optimum fish and wildlife conditions, and also considers the time of year of large flood control releases to be more important than their magnitude.

The adverse impacts of floodflows in Mexico would occur primarily as damages to agriculture in the flood plain between the river and the levees. The Government of Mexico has indicated a preference for alternative 8, which provides the highest level of control of magnitude and frequency of flood discharges from Lake Mead. However, the probability of higher discharges below Morelos Dam is greater in that alternative than in the others during the 1 August to 1 January space-building period because there would be longer periods of sustained high discharges from Lake Mead and, hence, a greater probability of concurrence of high river discharge and flood discharges from tributaries downstream from Lake Mead. Moreover, alternative 8 as discussed hereinafter would provide the lowest water conservation benefits.

Coordination of February 1981 Draft Report

A draft of this report, dated February 1981, was distributed to appropriate private interests, and local, State, and Federal agencies along with a formal request for comments on the study and its recommendations. Appendix G presents all written comments received along with responses to the issues raised. Nearly all the responses were favorable to the conclusions and recommendations adopted as a result of the study. The only clear preference for a plan other than the recommended plan of operation was the Arizona Game and Fish Department's choice of alternative 6, because this alternative would cause somewhat less annual fluctuation in the Lake Mead water surface elevation, thereby minimizing impacts on aquatic ecosystem in the lake.

COMPARISON OF PLANS

This section compares the alternative plans and establishes a rationale for selecting one of them for implementation.

Comparison of the magnitude of the relative net benefits of alternatives 2 through 9 against the net benefits for alternative 1, as given in table 4, shows that the economic impacts of Lower Colorado River flooding are not highly sensitive to the Hoover Dam flood control operation plan within the limits of the plans formulated. Only alternative 2 was superior to alternative 1 in the production of relative net benefits and then only by $33,000 annually. The difference in net benefits between alternatives 1 and 9 is negligible; alternative 9 would produce about $2,000 a year less than alternative 1 on a average annual basis. Alternative 8 produces the lowest annual net benefits, $740,000 a year less than alternative 1.

The reason for the relatively small spread in average annual benefits among the nine alternatives evaluated lies in certain features of the flood control operation common to all the plans. First, snowmelt flood releases are based on forecasts of reservoir inflow that are updated monthly. Hence, all plans have a self-adjusting (correcting) component that tends to produce similar total volumes of water released, and thereby, similar end-of-year water in storage. Second, the series of steps below 40,000 ft^3/s tend to produce lower annual peak release rates, but of longer duration. The resulting effect is that damaging flood control releases are minimized while hydropower generation is maximized and excess water is made available for diversion and use for longer period of time. Again, calling for stepped releases below 40,000 ft^3/s is common to all plans. Third, the relatively high degree of flood control afforded by all the plans means that differences in level of protection occur with fairly rare events that tend to be smoothed out in the computation of average annual costs and benefits.

Five plans (alternatives 2, 3, 7, 8, and 9) provide lower average annual flood damages than alternative 1. Average annual flood damages for these alternatives range from $8,000 to $39,000 less than alternative 1. The relatively small gains in flood protection are generally more than offset by reduced economic benefits in other areas considered (water conservation, hydropower, salinity, et al). Alternatives 4 and 5 provide less flood protection than alternative 1.

Based solely on the magnitude of economic benefits, water conservation is the most significant economic parameter effected by Hoover Dam flood control operation. Alternatives 1 and 9 would produce the highest water conservation benefits. Alternatives 3, 6, and 7 would cause more water to be held in Lake Mead at the end of the planning period, but the value of the stored water would be more than offset by reductions in diversions of excess water to MWD. Alternative 8 provides the lowest water conservation benefits.

Differences in effects on salinity among the alternatives are relatively small except for alternatives 4 and 8. Alternative 4 would increase salinity costs about $293,000 a year, whereas alternative 8 would reduce salinity costs by about $293,000 a year.

Alternatives 2 and 8 would provide for the highest level of hydropower generation. Both plans would produce a net average annual increase of 2 million kilowatt hours over alternative 1. Alternatives 3, 4, 6, and 7 would produce less hydropower than alternative 1.

Alternative 1 would require the least maintenance costs, and alternative 8 the highest maintenance costs; however, alternative 8 costs would only be $17,000 more than alternative 1.

THE NATIONAL ECONOMIC DEVELOPMENT (NED) PLAN

The plan that produces the greatest net economic benefits to the nation is designated as the National Economic Development (NED) plan. Of the nine alternatives considered, alternatives 1, 2, and 9 best fit the NED definition.

None of the alternative plans has demonstratively greater environmental or social benefits. The small advantage that alternative 8 might appear to have based on frequency and timing of annual peak flows would be offset, at least in part, by increased duration of high flows.

THE PLAN SELECTED

Alternative 1, which retains the same storage allocation for flood control as the 1968 plan of operation, is selected as the plan to be recommended for implementation because of the high rate of economic benefits relative to the other alternatives. The slightly higher economic benefits generated by alternative 2 were not deemed sufficient to warrant an increase in 1 January flood control from 5.35 MAF to 5.67 MAF. The sensitivity of the determination of net benefits to relatively small changes in the value of economic factors makes the difference in average annual net benefits of $33,000 between alternatives 1 and 2 insignificant. None of the plans has a significant advantage over alternative 1 in effects on the environment. Alternative 8 would produce less negative social impacts than alternative 1, but not enough to outweigh a comparatively poor performance in water conservation.

All the alternatives provide a relatively high degree of flood control protection. The objective was to determine the plan that, within the framework of flood control operation, generated a high level of economic benefit in the areas of hydropower generation and water conservation with minimal adverse environmental and social impacts. Alternative 1 meets that criterion.

SUMMARY

Hoover Dam is the only structure on the main stem Lower Colorado River with dedicated flood control storage. Prior to the construction of Hoover Dam, high flows occurred seasonally along the Lower Colorado River and damaging flows were common. When Hoover Dam was completed in 1935, control of most floods on the Lower Colorado River to an outflow of 40,000 ft^3/s became possible. Few, if any, structures were located in the 40,000 ft^3/s flood plain of the Lower Colorado River in 1935 and for some years thereafter. For many years the flood control operation plan for Hoover Dam has incorporated a "target maximum" release of 40,000 ft^3/s not to be exceeded unless absolutely necessary. Encroachment of development into the flood plain in the past several decades, however, has created a situation in which significant damages would now result from a release of 40,000 ft^3/s from Hoover Dam.

The construction of a system of reservoirs upstream from Hoover Dam from 1962 to 1966 eliminated the need for flood control releases between 1963 and 1980. With the filling of Lake Powell, a larger than normal runoff year could require flood releases that would produce damaging flows downstream from Hoover Dam.

Aside from some low-lying agricultural, recreational, and wildlife preserve areas, the residential and commercial development of the Parker Strip just below Parker Dam is the reach most vulnerable to flood damages. Damages that would result from a flow of 30,000 ft^3/s through Parker Strip are estimated at $150,000. Damages in the Parker Strip would increase rapidly as flows increase above 30,000 ft^3/s. At Needles, minor damages would occur from flows of 40,000 ft^3/s. At 40,000 ft^3/s damages in the Needles reach would be about $1.8 million, mostly to agricultural development. At Blythe, a 50,000 ft^3/s flood would cause estimated damages of about $140,000 to residential property and mobile homes, and total damages of about $1.2 million. At Yuma, all but extremely rare floods would be contained between the existing levees. Development, however, has taken place between the levees. A flow of 16,000 ft^3/s would flood some low-lying fields. A flow of 40,000 ft^3/s would flood many fields and a number of buildings. A flow of 70,000 ft^3/s would flood virtually all development between the Yuma levees, including about 40 buildings, irrigation canals, and extensive cultivated fields.

Because Hoover is a multipurpose dam, water conservation, power production, recreation, and maintenance of the natural environment, as well as flood control, must be given adequate consideration in the development of a flood control operation plan.

In order to demonstrate the effects of favoring flood control, water conservation, and power generation in turn, nine alternative operation plans designed to favor each of the three purposes to varying degrees were formulated and analyzed. Of these plans, alternative 1 was selected as the plan to be implemented. Major features of the plan are:

1. It requires that a minimum 1.5 million acre-feet of storage space be made available on 1 August of each year for the control of rainfloods.

2. It requires that a minimum storage space of 5.35 MAF be made available on 1 January of each year for the control of snowmelt floods during the spring and summer.

3. It has a maximum controlled release of 73,000 ft^3/s to be exceeded only by uncontrolled spillway flows.

4. Space-building releases to provide required 1 January storage space begin on 1 August of each year.

5. Space-building releases through the period of August through December are limited to 28,000 ft^3/s.

6. The selected plan incorporates a set of release steps of 19,000; 28,000; 35,000; 40,000; and 73,000 ft^3/s to be used for the control of snowmelt floods.

7. Reservoir operation during the months of January through July are based on a snowmelt runoff forecast updated monthly.

8. Available storage space in Lake Powell and effective storage space in other upstream reservoirs may be counted in lieu of space in Lake Mead.

There would be no direct costs for implementing the selected plan. The plan would produce economic benefits roughly equal to or better than any of the alternatives studied.

The selected plan would not have environmental impacts significantly different from the other plans as described in the Finding of No Significant Impact and Environmental Assessment in appendix E.

CONCLUSIONS

The District Engineer concludes that:

1. A high probability exists that flood control releases of a damaging magnitude will be required from Hoover Dam within the next 10 years.

2. A flood control operation plan for Hoover Dam can best be defined by specified storage-space requirements for 1 August through 1 January of each year and a series of incremental releases or release steps to be applied from 1 January to 1 August. The step release to be applied during a given month would depend upon storage space available and the monthly updated runoff forecast.

3. The 1968 operation plan called for space-building releases during the months of October through December. Extending this period to August through December would have the effect of reducing the size of required flows and, consequently, reducing the potential for flood damages without any adverse effects. During the August-through-December period, when no runoff forecast is available, space-building releases that would cause damage to inhabited structures are not justified. Therefore, sustained releases during this period should be limited so as to not exceed 28,000 ft^3/s, presently estimated as the largest release from Hoover Dam that will not damage inhabited structures. It is concluded that the recommended revised flood control criteria for Lake Mead and Hoover Dam could create little, if any, effect on the operation of Lake Powell. The space building requirements would not, of themselves, cause greater flow rates or volumes below Glen Canyon than have occurred historically or would have been expected under the 1968 regulations.

4. The alternative plans presented in this report encompass a range of storage provisions and step-release patterns to demonstrate the effect of varying these criteria.

5. Alternatives 1, 2, and 9 would produce greater net benefits than any other alternative. Net benefits for these three plans would be about the same. Alternative 1 more closely approximates the current plan of operation than any other alternative considered. Alternative 8 provides the least net benefits.

6. Alternative 8 would produce the greatest reduction in flood damages and, as a result, would have the most favorable social impacts. The advantage is not sufficient, however, to offset the plan's large detrimental effect on water conservation.

7. None of the plans would have a significant advantage in impacts on the natural environment (reference, the Finding of No Significant Impact and Environmental Assessment in appendix E).

8. Of the alternative flood control operation plans studied, alternative 1 is the best compromise among the many purposes of Hoover Dam. The plan: (1) provides a high degree of flood control, (2) produces net economic benefits approximately equal to or better than any of the other alternatives, and (3) causes no significantly increased environmental damages over the other alternatives.

9. Executive Order 11988, Flood Plain Management, dated 24 May 1977, encourages the preservation of flood plains in their natural state, thereby providing for the passage of floodflows without damage to development. Implementation of the selected plan, alternative 1, would not affect any construction in the Lower Colorado River flood plain. Also, the plan in itself would neither encourage nor discourage construction in the flood plain. Under any of the alternative plans studied, a large flood would tend to discourage further encroachment into the flood plain.

10. No direct costs would be incurred by the implementation of the selected plan.

RECOMMENDATIONS

The District Engineer, U.S. Army Corps of Engineers, and the Regional Director, Bureau of Reclamation, recommend that:

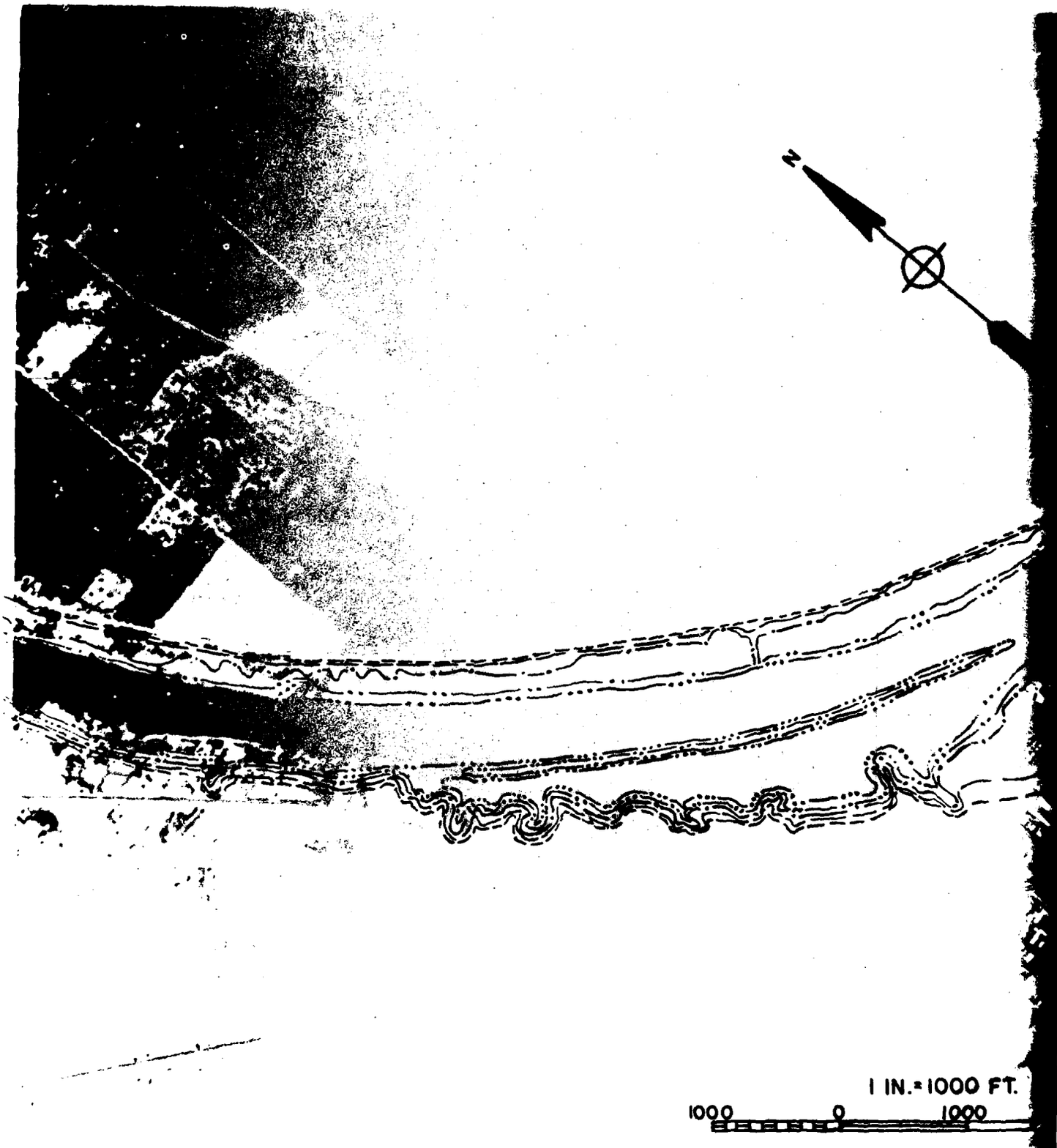
1. Alternate 1 be adopted and implemented as the flood control operation plan for Hoover Dam, and that all relevant operation manuals and documents be revised to reflect the provisions of the selected plan.

2. The Hoover Dam flood control operation plan be reviewed for appropriateness and relevance after the full implementation of the Central Arizona Project taking into account also the effects of increased uses of water in the Upper Colorado River Basin.

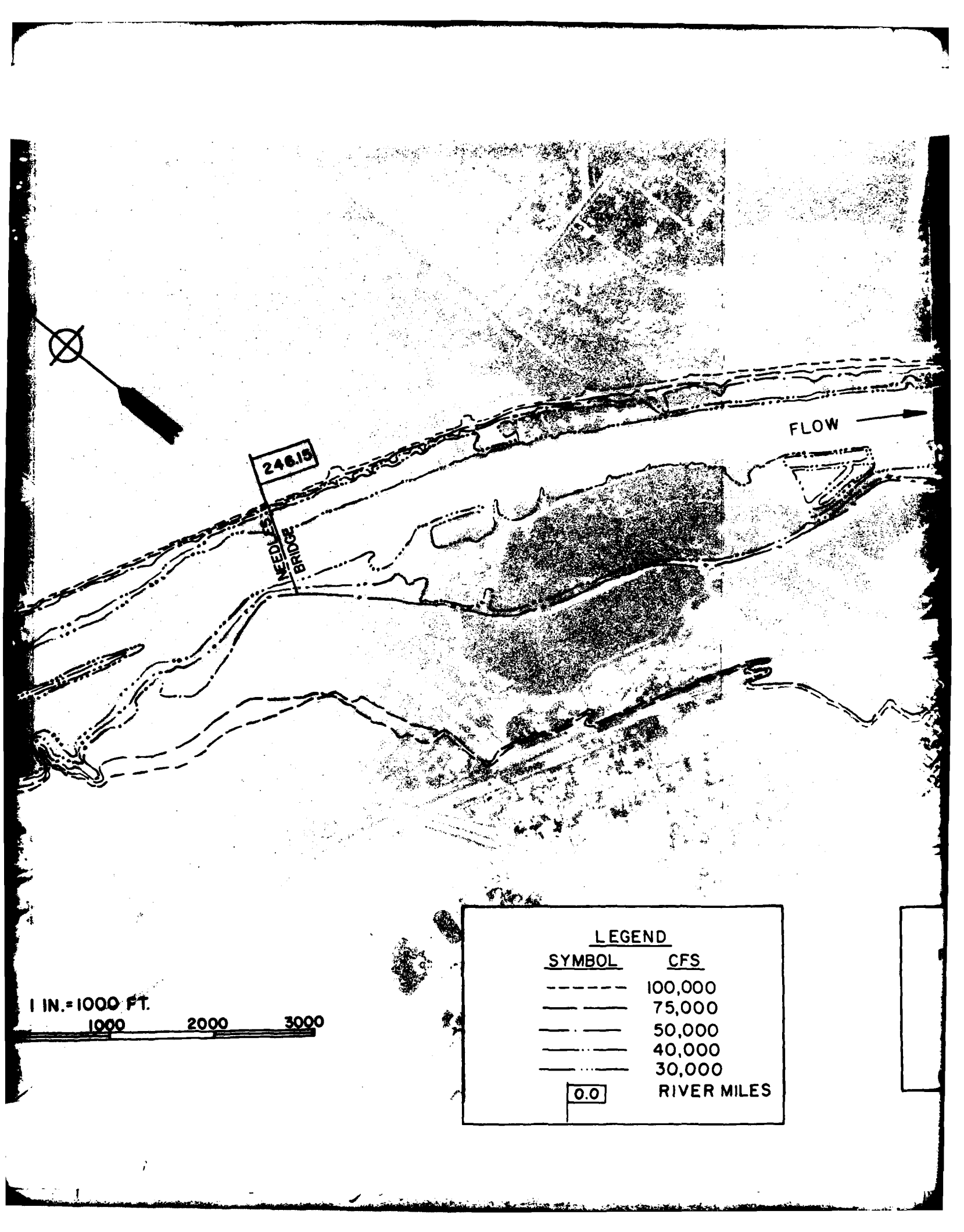
3. The Bureau of Reclamation will continue a policy of vigorous implementation of Executive Order 11988, Flood Plain Management, with the objective of minimizing development of flood-prone land along the Lower Colorado River.

PAUL W. TAYLOR
Colonel, CE
District Engineer

N. W. PLUMMER
Bureau of Reclamation
Regional Director



HD-5


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NEEDLES BRIDGE
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COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

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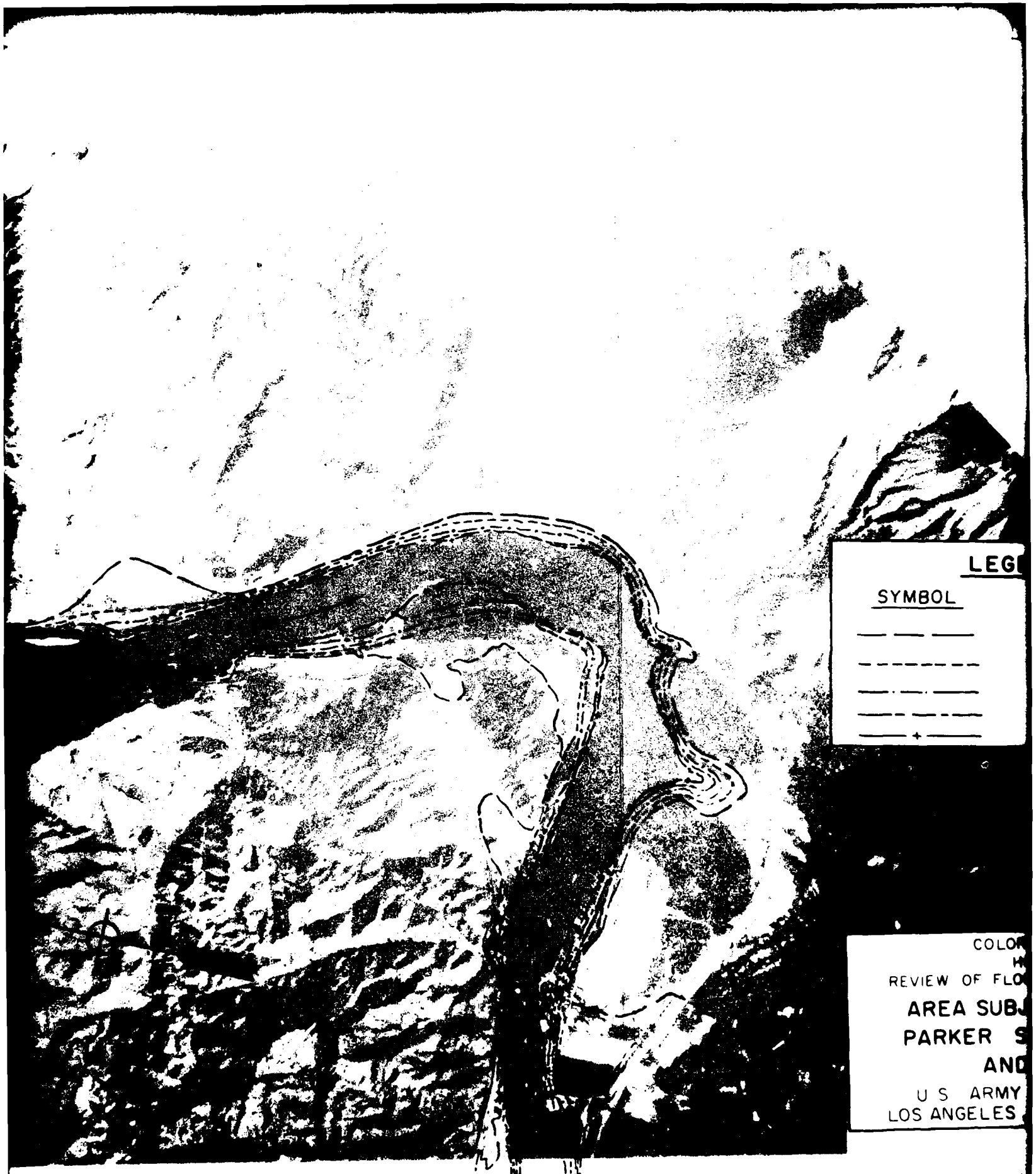
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LOS ANGELES, CORPS OF ENGINEERS

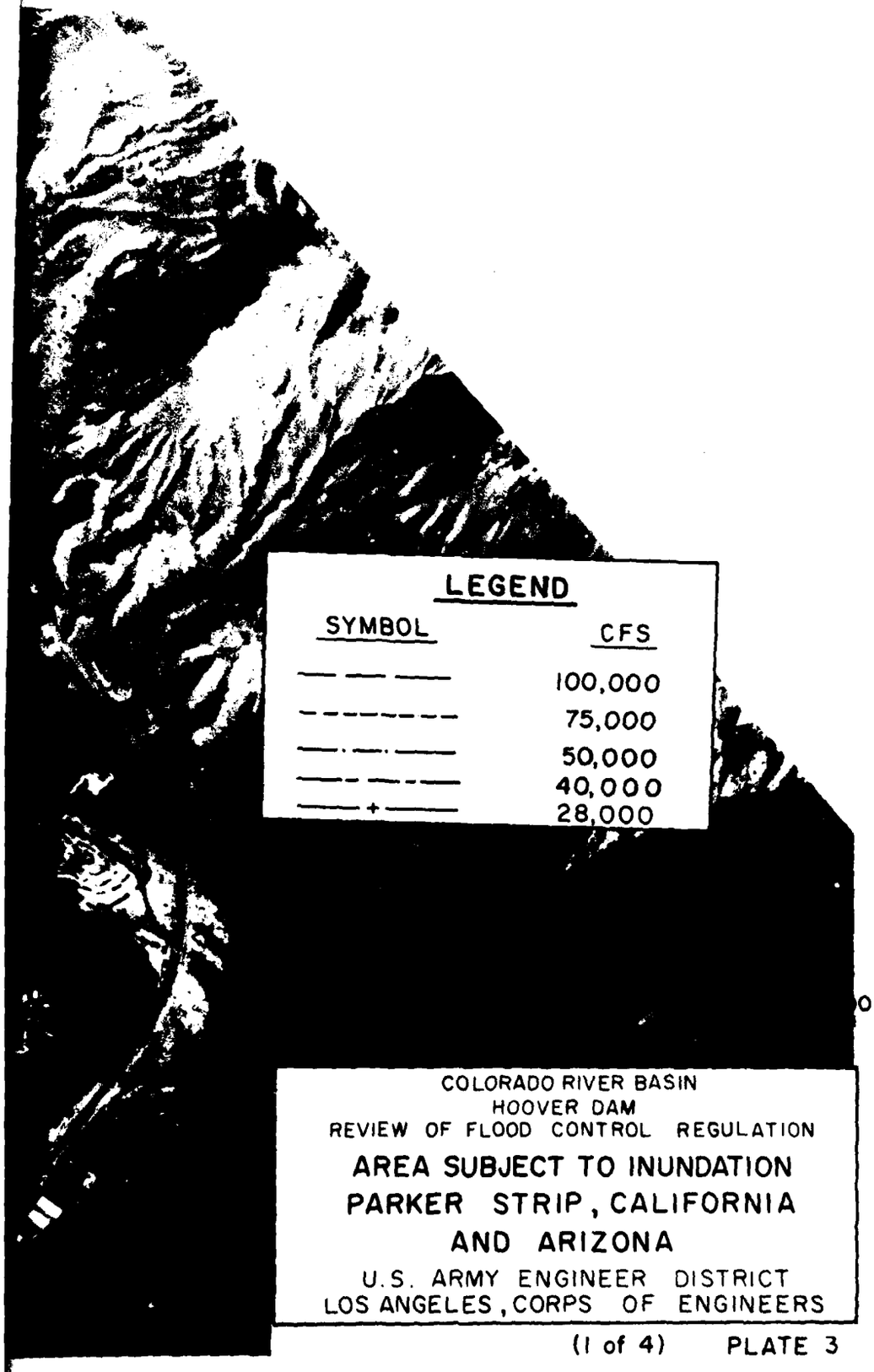
PLATE 2



HD-6



MATCH TO PLATE 3 (2 of 4)



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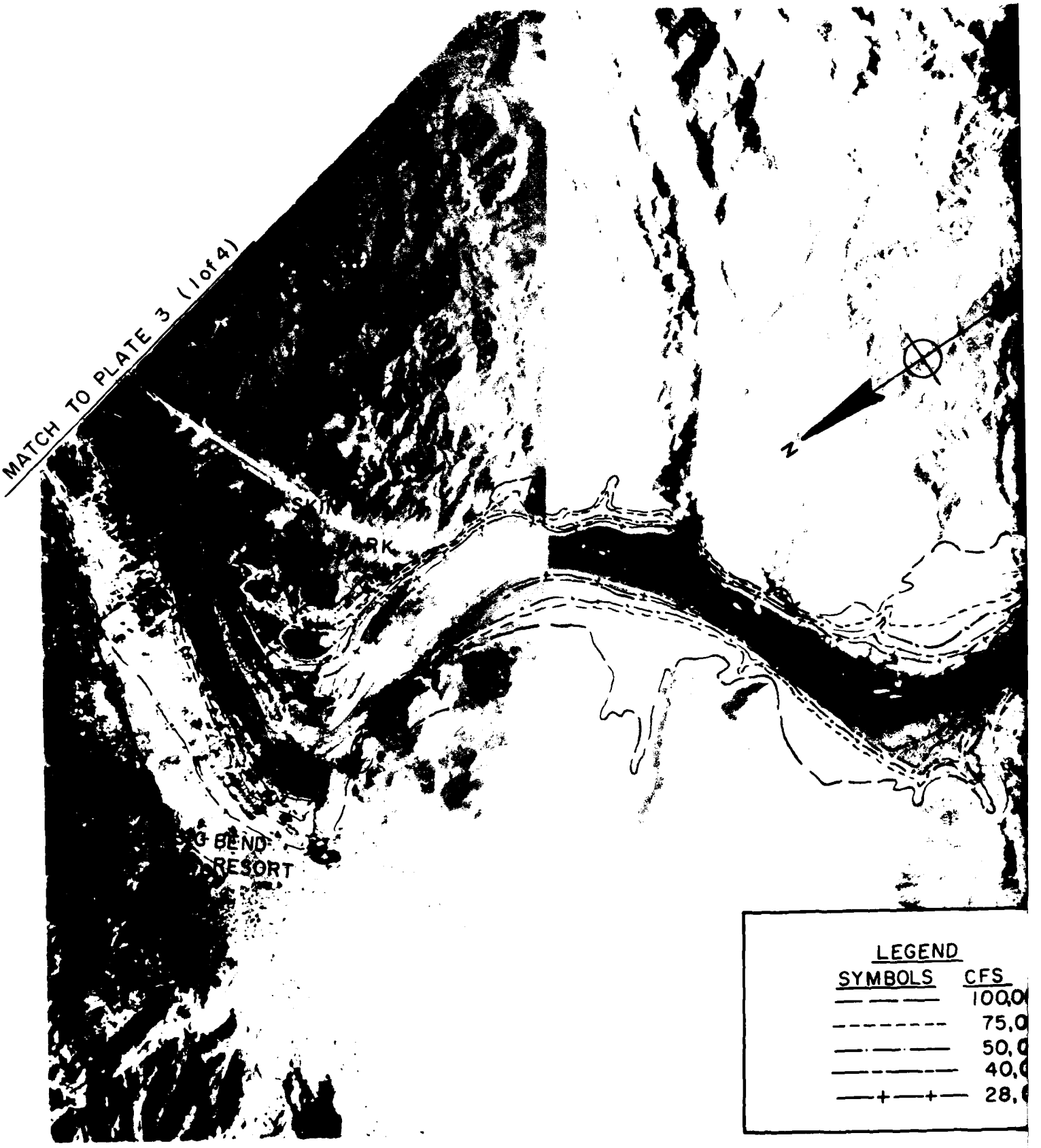
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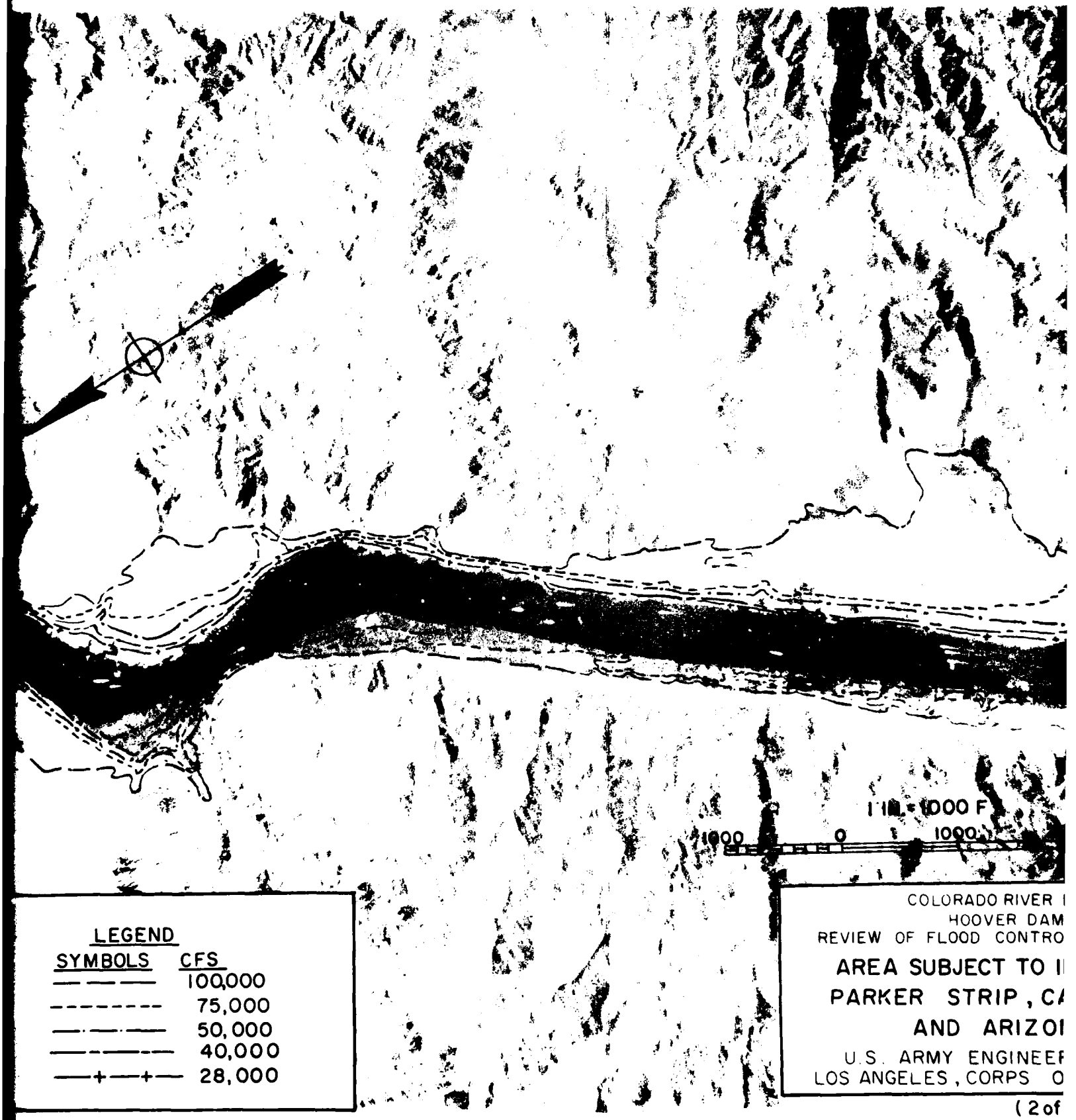
COLORADO RIVER BASIN
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REVIEW OF FLOOD CONTROL REGULATION

AREA SUBJECT TO INUNDATION
PARKER STRIP, CALIFORNIA AND ARIZONA

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

(1 of 4) PLATE 3


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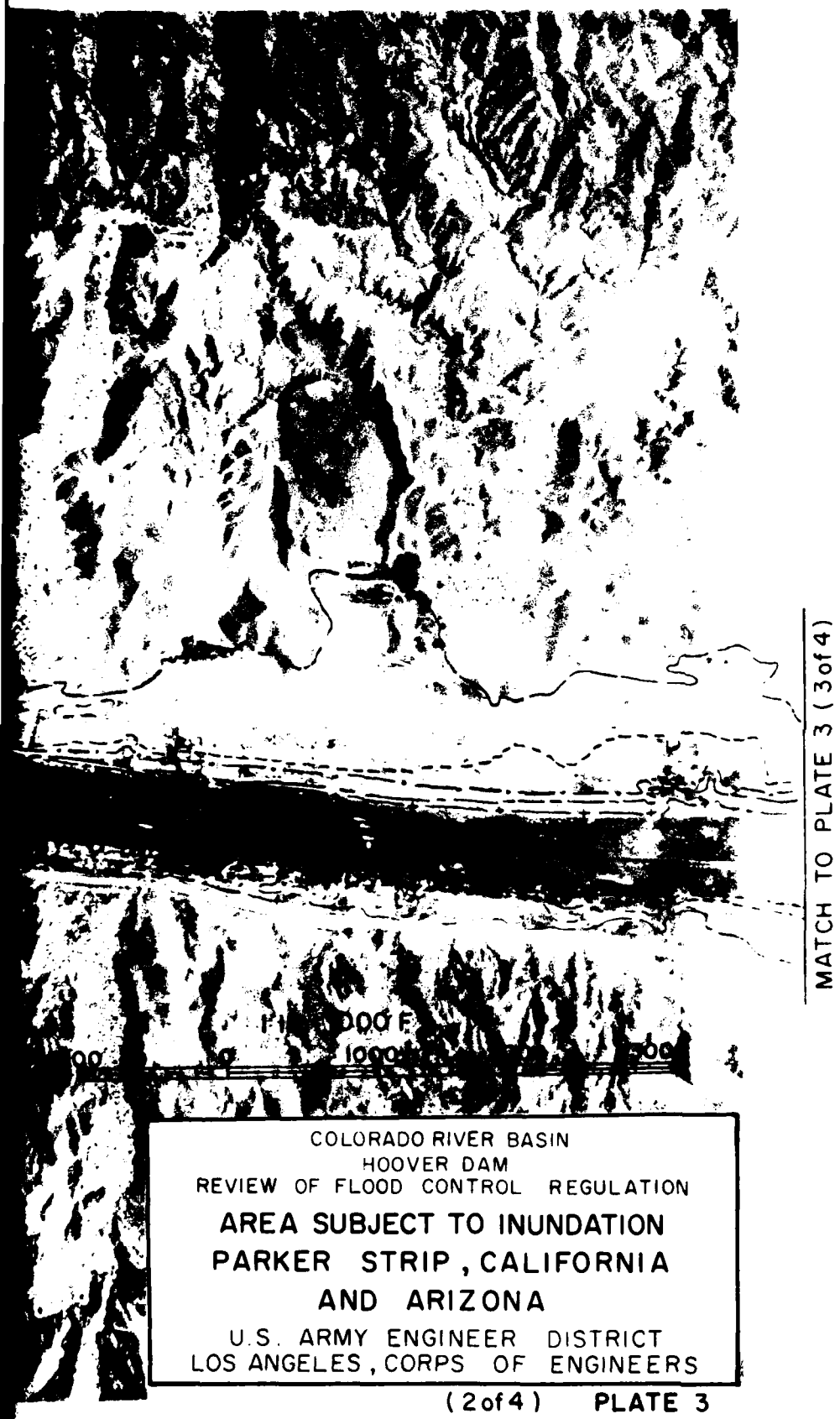


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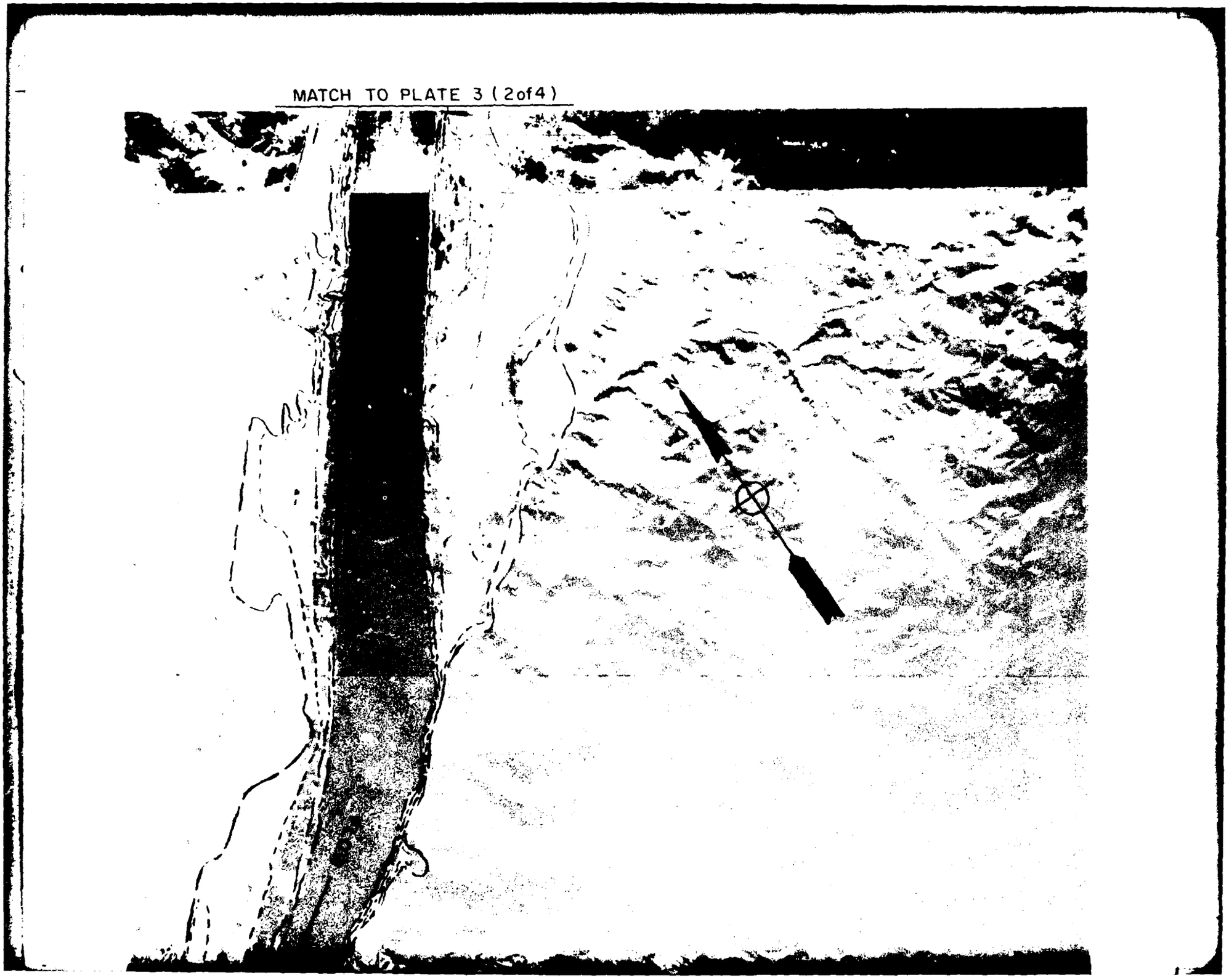
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HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

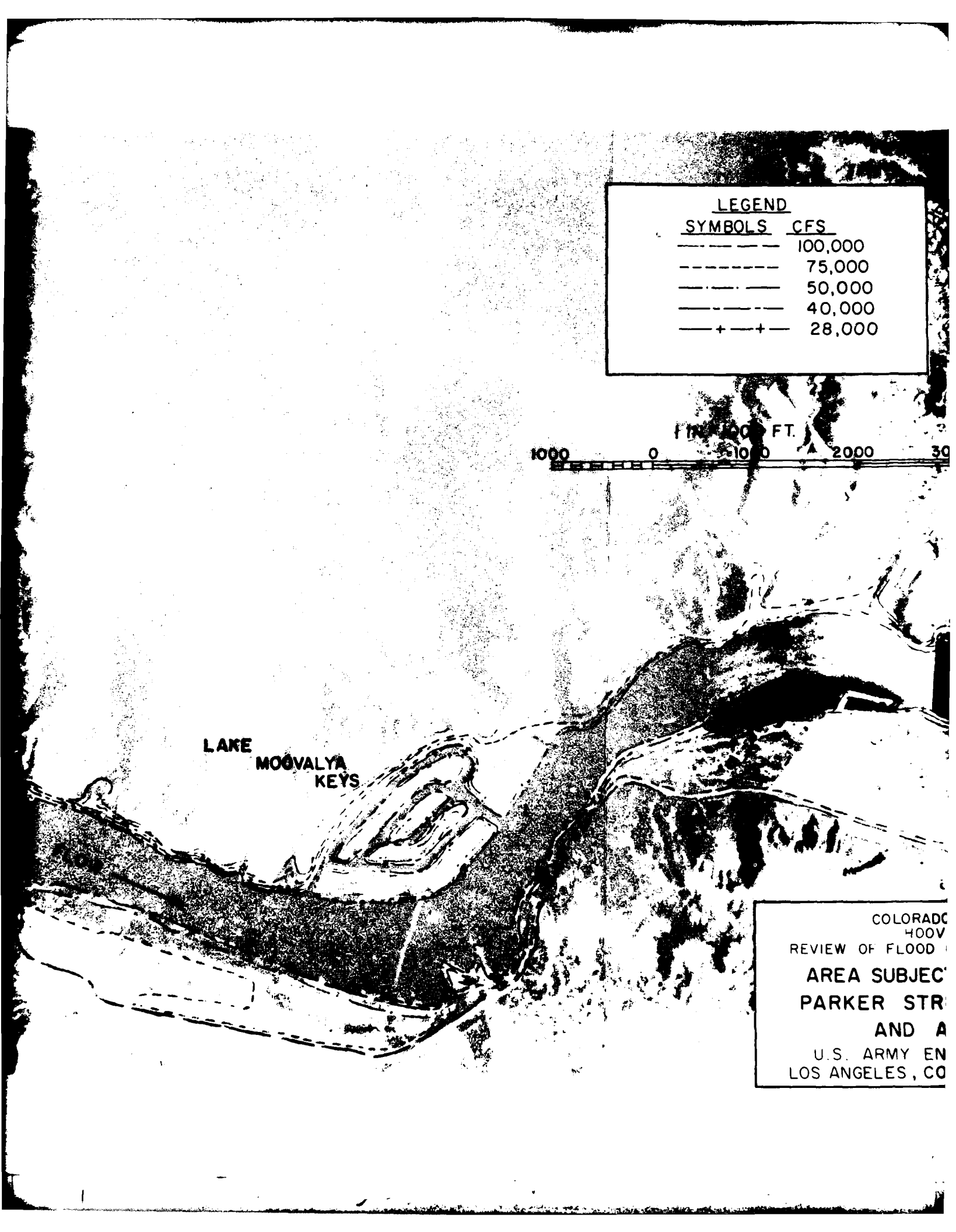
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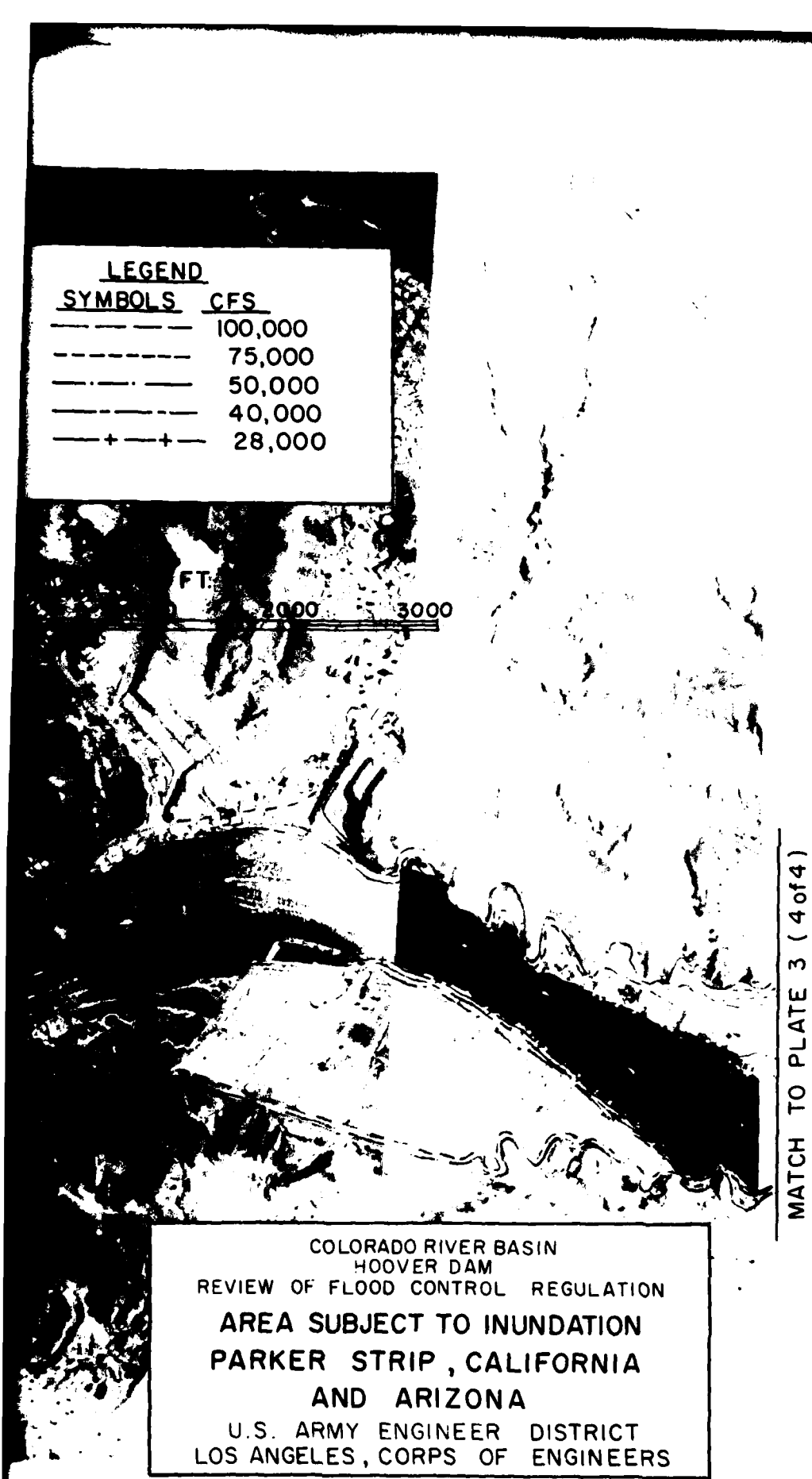
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(2of4) PLATE 3

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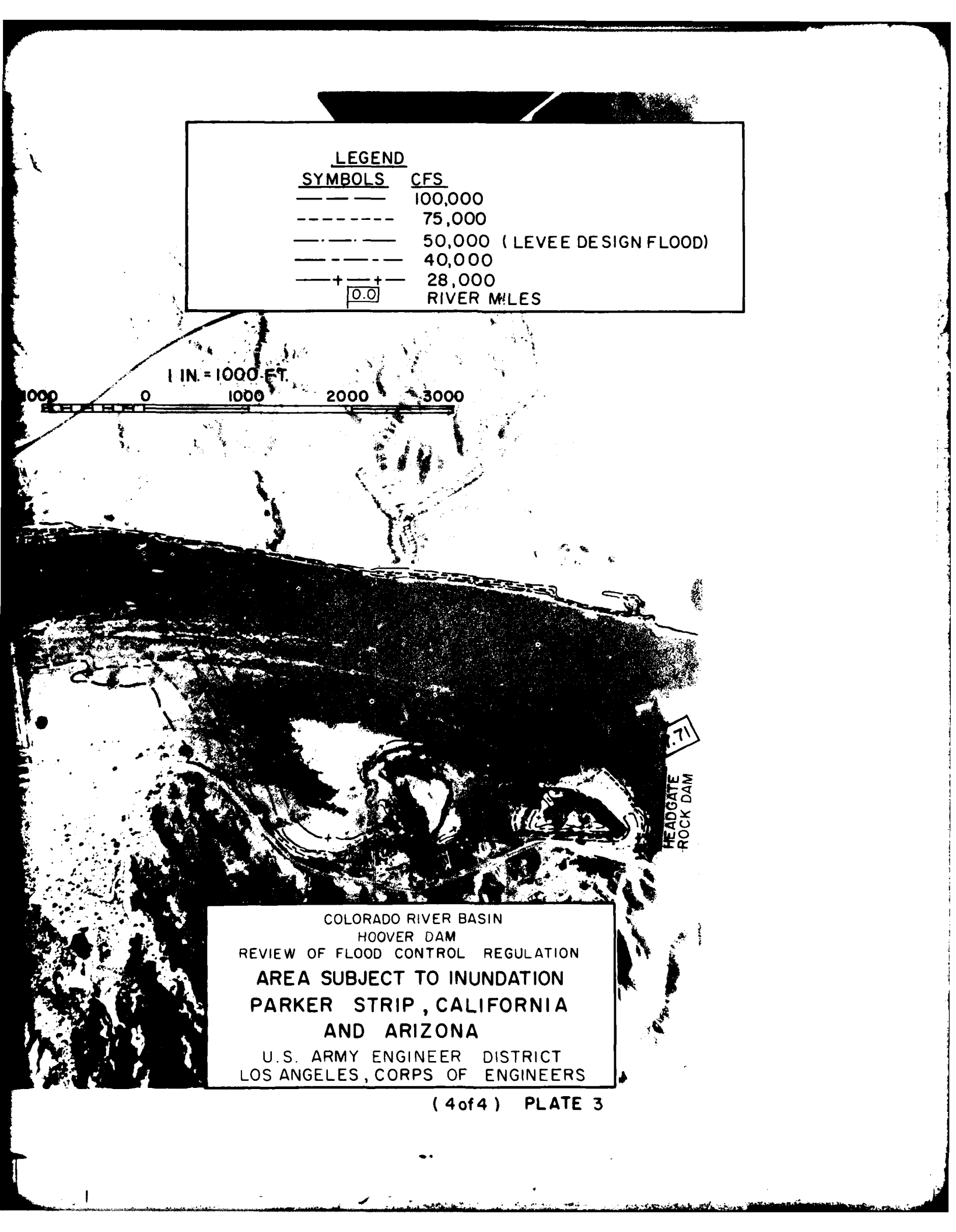
COLORADO RIVER BASIN
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REVIEW OF FLOOD CONTROL REGULATION

AREA SUBJECT TO INUNDATION
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U.S. ARMY ENGINEER DISTRICT
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(3of4) PLATE 3


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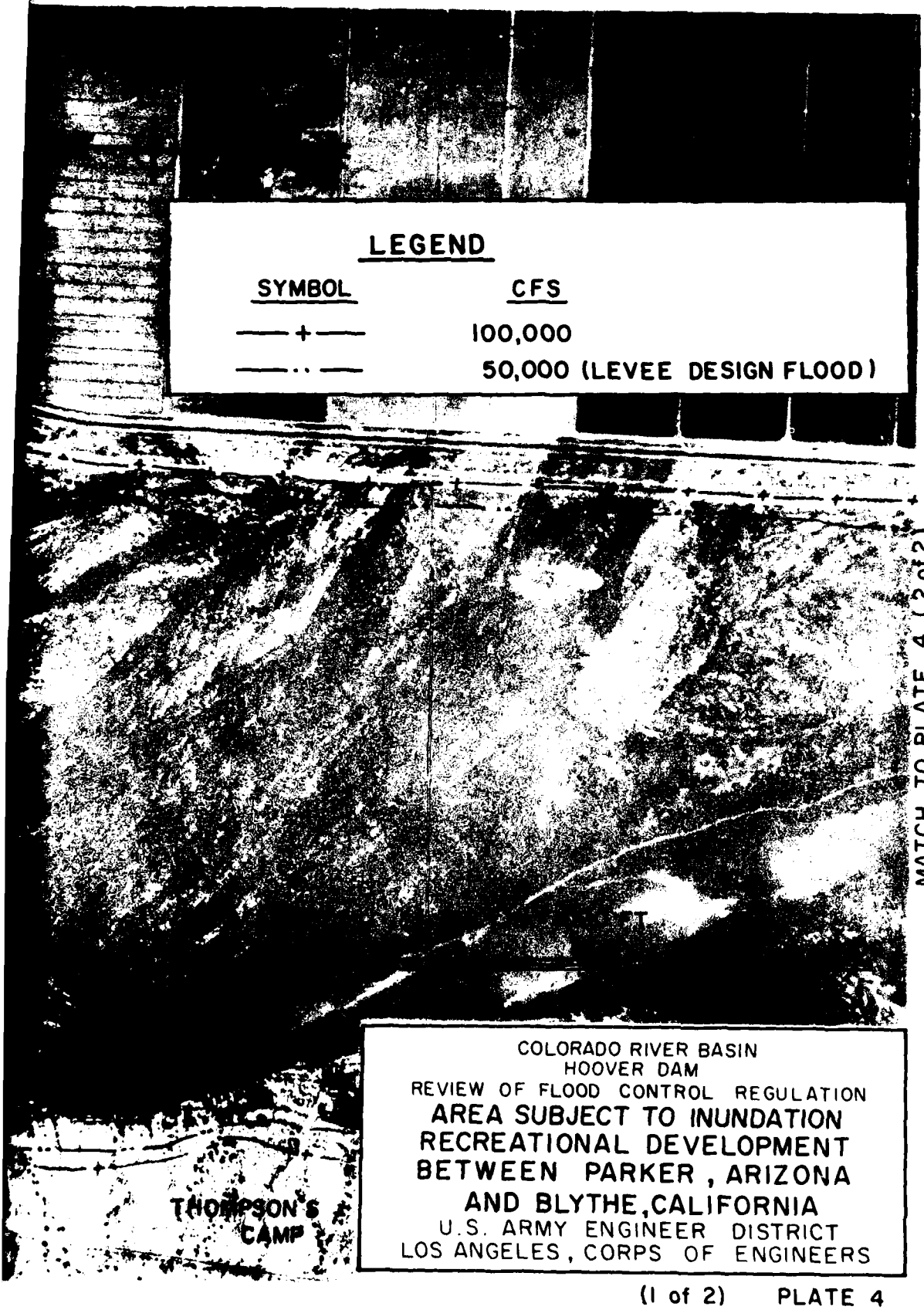


COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

AREA SUBJECT TO INUNDATION PARKER STRIP, CALIFORNIA AND ARIZONA

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS


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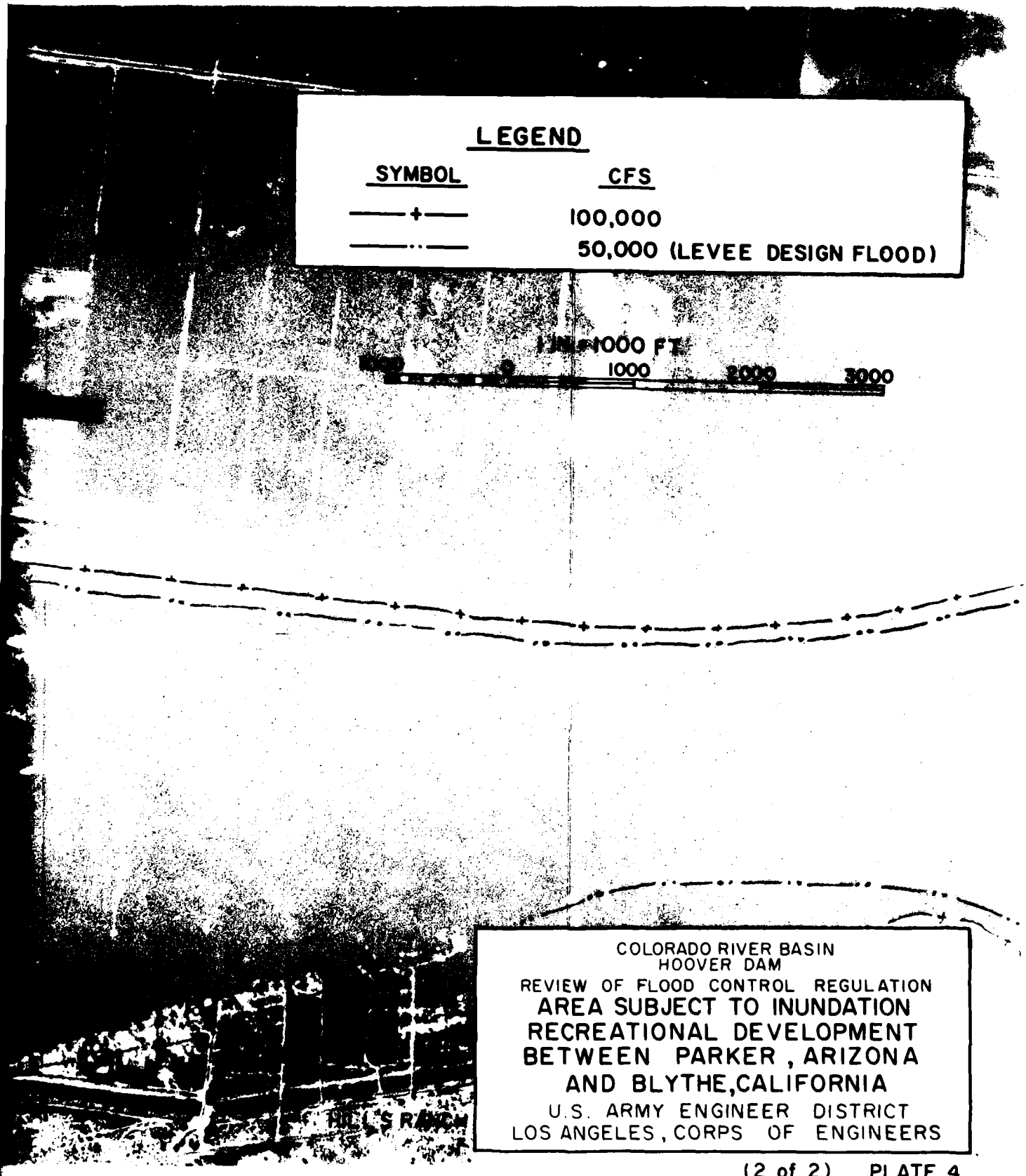


MATCH TO PLATE 4 (2 of 2)

COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION
AREA SUBJECT TO INUNDATION RECREATIONAL DEVELOPMENT BETWEEN PARKER, ARIZONA AND BLYTHE, CALIFORNIA
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

(1 of 2) PLATE 4

HD-11



COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION
AREA SUBJECT TO INUNDATION RECREATIONAL DEVELOPMENT BETWEEN PARKER, ARIZONA AND BLYTHE, CALIFORNIA
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

(2 of 2) PLATE 4

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SYMBOL	CFS
——— — — ———	75,000 (LEVEE DESIGN FLOOD)
——— · · ———	50,000



NOTE:
LIMITS OF 100,000 CFS FLOOD AND EASTERN LIMITS OF 75,000 CFS FLOOD ARE OFF PLATE.



COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

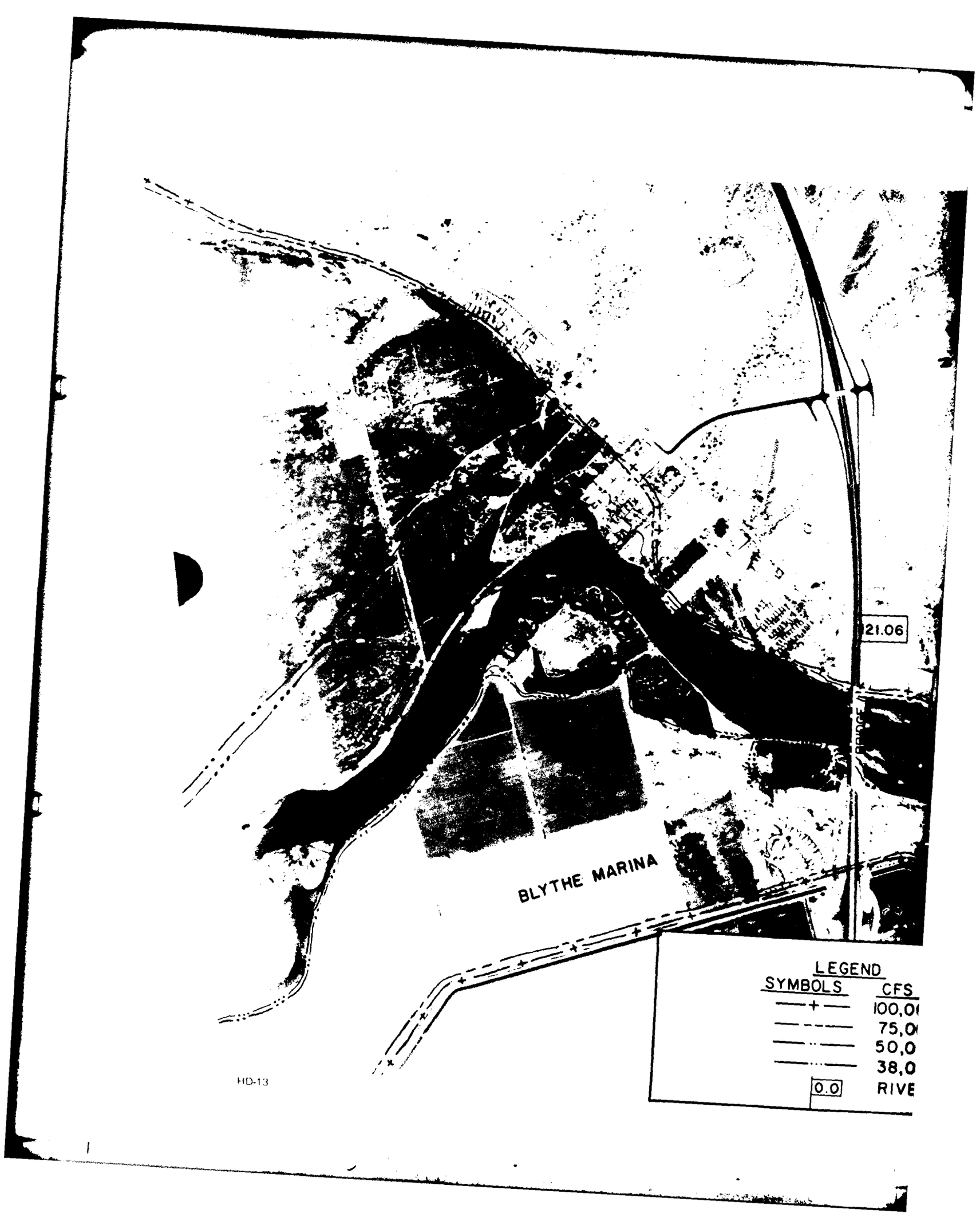
AREA SUBJECT TO INUNDATION RETIREMENT AND RECREATIONAL DEVELOPMENT NEAR BLYTHE, CALIFORNIA

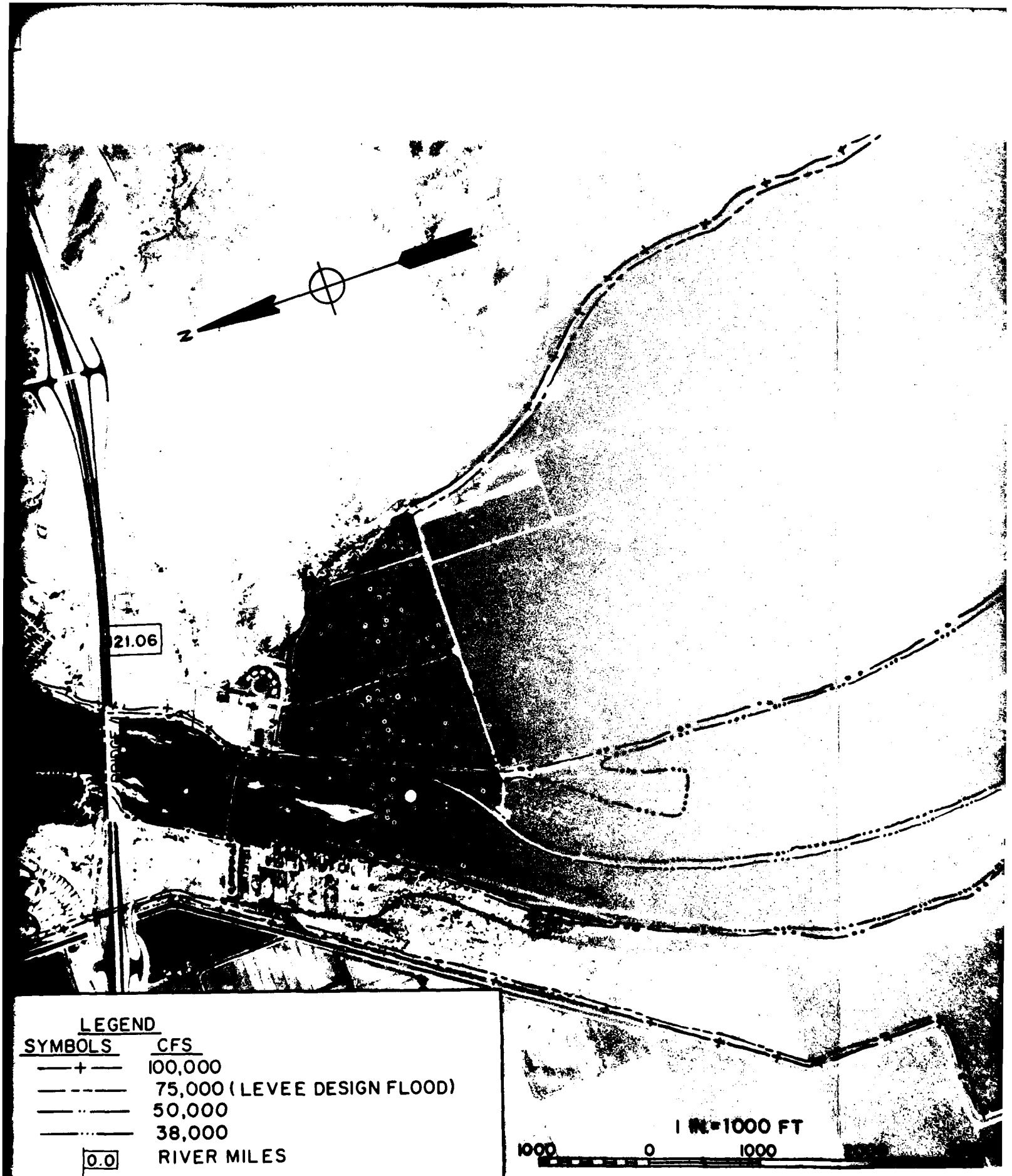
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LOS ANGELES, CORPS OF ENGINEERS

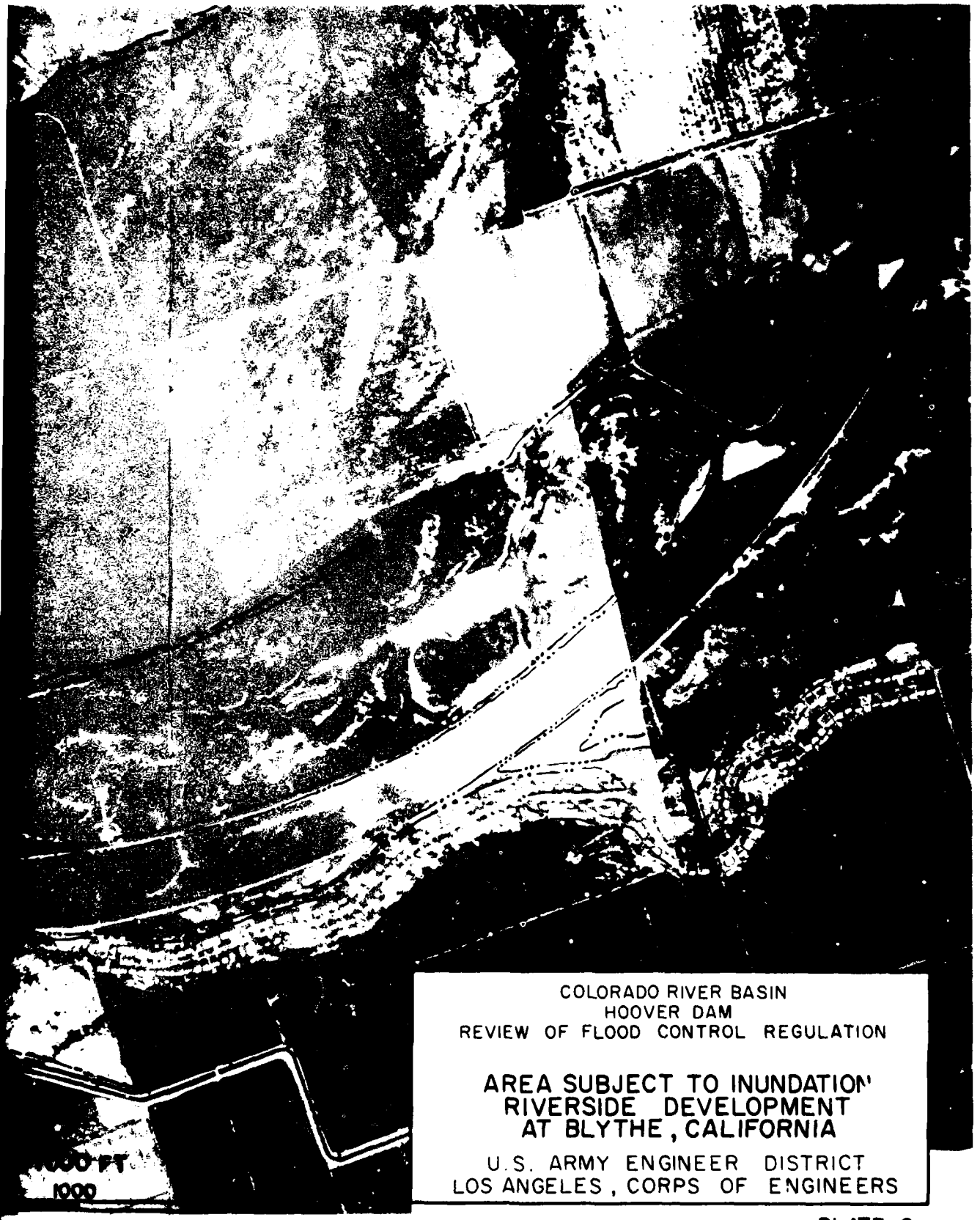
PLATE 5

LIMITS OF 100,000 CFS FLOOD AND EASTERN LIMITS OF 75,000 CFS FLOOD ARE OFF PLATE.

000 FT.
1000 2000 3000


21.06
BLYTHE MARINA
LEGEND
SYMBOLS
CFS
100,0
75,0
50,0
38,0
0.0
RIVE


N
21.06
BRIDGE
LEGEND
SYMBOLS
CFS
100,000
75,000 (LEVEE DESIGN FLOOD)
50,000
38,000
0.0
RIVER MILES
1 IN.=1000 FT
1000
0
1000

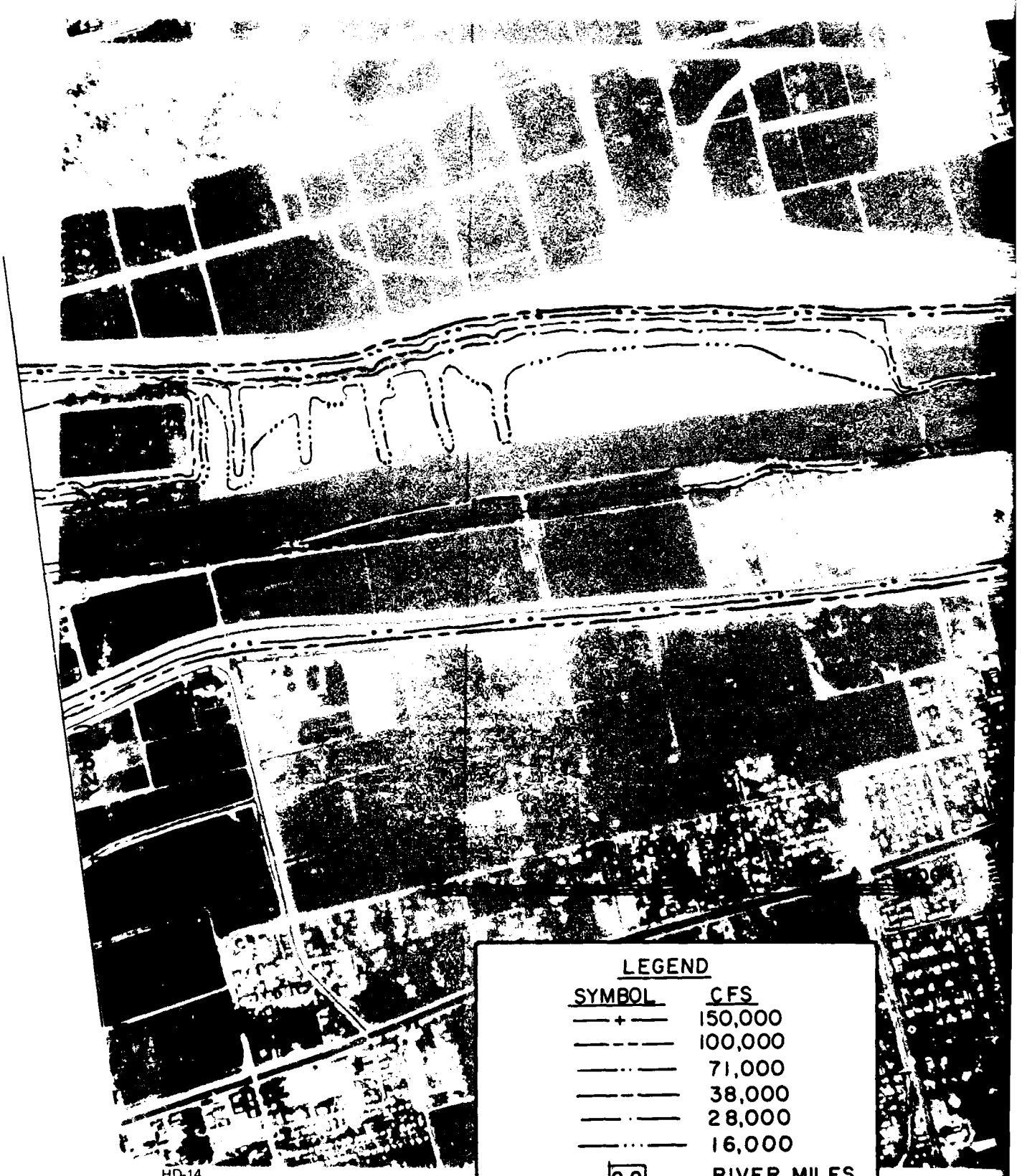


COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

AREA SUBJECT TO INUNDATION RIVERSIDE DEVELOPMENT AT BLYTHE, CALIFORNIA

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PLATE 6


LEGEND
SYMBOL
CFS
150,000
100,000
71,000
38,000
28,000
16,000
0.0
RIVER MILES

HD-14



FS
0,000
0,000
1,000
8,000
8,000
6,000
IVER MILES

COLORADO RIVER BASIN
HOOVER DAM
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(1 of 2)

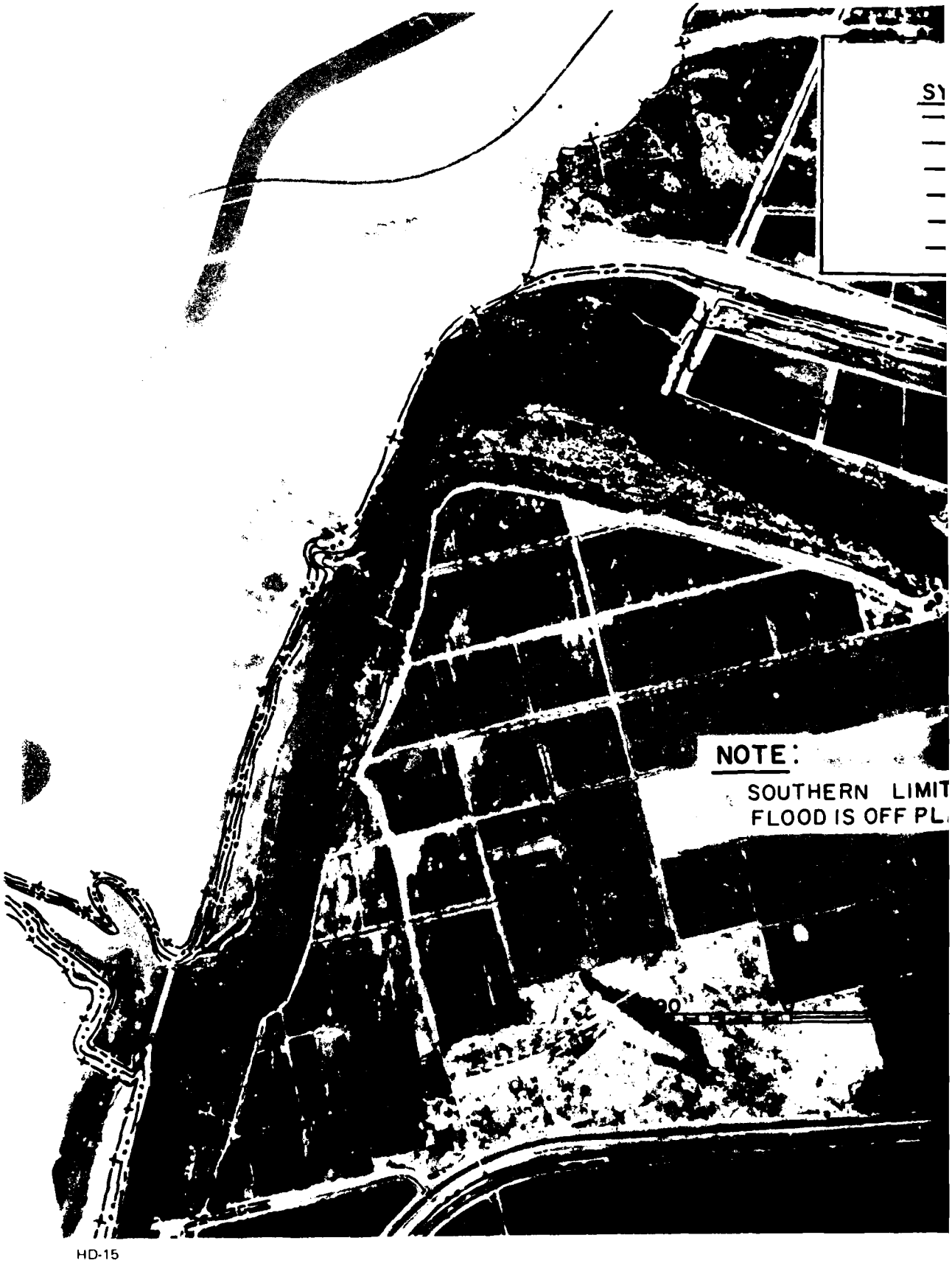


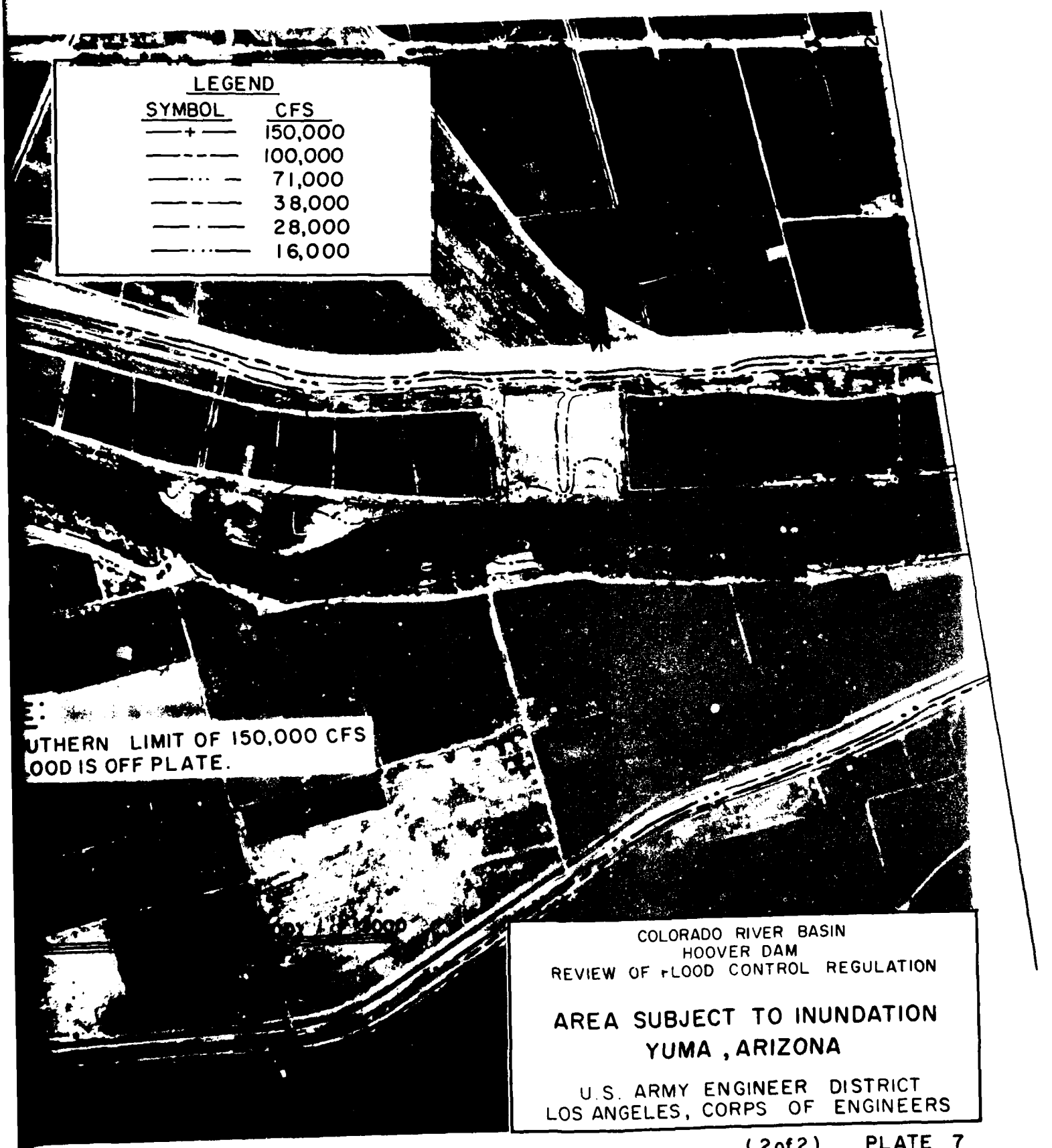
COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

AREA SUBJECT TO INUNDATION
YUMA, ARIZONA

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LOS ANGELES, CORPS OF ENGINEERS

(1 of 2) PLATE 7


NOTE:
SOUTHERN LIMIT
FLOOD IS OFF PL



COLORADO RIVER BASIN
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REVIEW OF FLOOD CONTROL REGULATION

AREA SUBJECT TO INUNDATION
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(2of2) PLATE 7

APPENDIXES

APPENDIXES

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D. EVALUATING THE THREAT OF OVERFLOWS INTO THE UNITED STATES

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G. AGENCIES' VIEWS AND RESPONSES

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ENGINEERING

Appendix A

ENGINEERING

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A-6 Water-surface profiles near Blythe, California.

A-7 Water-surface profiles at Yuma, Arizona.

Appendix A

ENGINEERING

FREQUENCY ANALYSIS

1. In support of damage frequency determinations described in appendix C and the main report, volume-frequency curves were developed at Lees Ferry and for five reaches of the Colorado River between Hoover Dam and the Gulf of California. Diversions from the river and flood control storage at Parker Dam dictated the selection of the reaches. The five reaches are (a) Hoover Dam to Parker Dam, (b) Parker Dam to Headgate Rock Dam, (c) Headgate Rock Dam to Imperial Dam, (d) Imperial Dam to Morelos Dam, and (e) Morelos Dam to the Gulf of California.

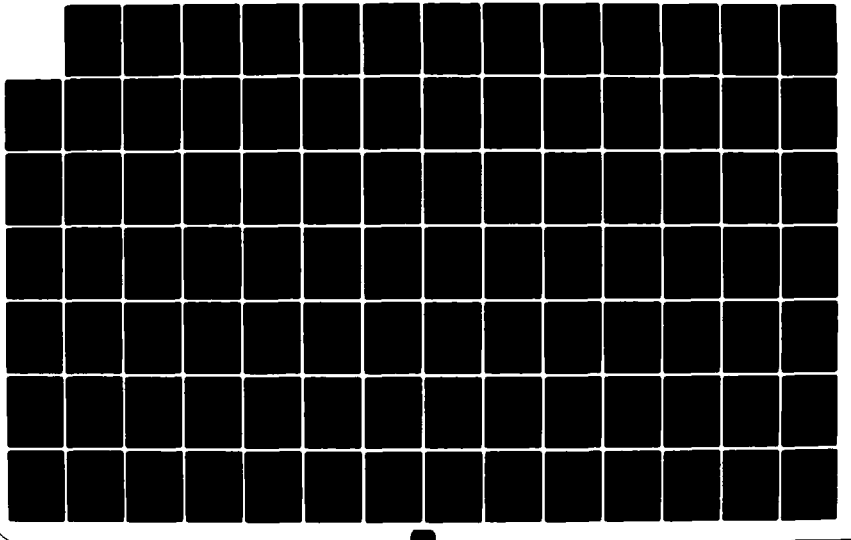
2. The frequency analysis utilized monthly flow values generated by the Bureau of Reclamation's Colorado River Storage Project (CRSP) Simulation Model at Hoover, Davis, and Parker Dams based on the historical streamflow records beginning in 1905. Subtraction of the appropriate net average monthly diversions from the releases at Parker Dam determined the downstream flow values in reaches from Parker Dam to the Gulf of California. The regulated frequency curves for durations of 1, 6, and 12 months were developed for the five reaches. Volume-frequency curves were also developed at Lees Ferry under natural (virgin) flow conditions.

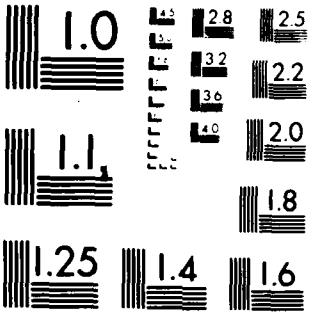
Runoff Data

3. Gage height records on the Colorado River at Yuma are available from 1878, but discharge measurements date only from 1902 to the present. Additional main-stem Colorado and tributary gaging stations were established about 1905. Dependable records have been taken at Lees Ferry beginning in 1922. The Bureau of Reclamation developed natural flow tables at about a dozen locations in the upper basin, plus the Colorado River at Lees Ferry. Through correlation with recorded data, monthly flow values starting in October 1905 have been determined at all the stations. These monthly flow values, modified and routed through the system under present reservoir operation criteria, are the basis for the discharge-frequency analysis. The monthly natural flow values at Lees Ferry were also analyzed and unregulated frequency curves developed. These unregulated curves were used to estimate the magnitude of rare events beyond the period of record. Table A-1 lists the natural flow of values at Lees Ferry, which are 13 April 1977 data base values.

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System Analysis

4. The modified monthly flow values for the period 1905-77 were routed through the Colorado River system by the Bureau of Reclamation using its CRSP Simulation Model. Basin development, diversions, and depletions were taken as average values estimated for 1980. Routing of the entire length of record using the same basin conditions provided flow values that would be expected to occur under 1980 conditions. The routings were performed for all nine alternatives studied. The reservoirs were assumed full to minimum flood control space (1.5 MAF) at the start of the period. The operating criteria and storage requirements for Hoover Dam and upper basin reservoirs for the nine alternatives are described in the main report. The CRSP Simulation Model operates on a volume basis with monthly flows adjusted for depletions, diversions, bank storage, and evaporation. These monthly outflow volumes were converted to monthly average flow rates in cubic feet per second. The outflow data was analyzed on the basis of annual maximum events. The operation for all alternatives was based on starting releases in August to obtain the required 1 January space. Table A-2 presents the regulated monthly Lake Mead historical inflow for 1980 conditions for alternative 1. The regulated inflow sequences vary with each alternative because of the different storage allocations, release steps, and the influence of these factors on upstream reservoir operation. Table A-3 presents the monthly Hoover Dam releases for the historical inflow record given in Table A-2 for alternative 1. Table A-4 summarizes the average monthly depletions and diversions applied to Hoover Dam releases in generating downstream flow data.

5. Analytical frequency analysis is not appropriate for watersheds altered by reservoirs. However, the natural flows at Lees Ferry were analyzed, and analytical frequency curves were developed.

6. The regulated monthly flows were ordered and plotted using median plotting positions according to the following equation:

$$P = \frac{(m - 0.3)}{(n + 0.4)} 100$$

where P is plotting position in percent or exceedance frequency in events per 100 years; m is the order number of the event; and n is the number of years of record.

7. A graphical best-fit curve was drawn through the plotted data. Plate A-1 shows the 1-, 6-, and 12-month curves for the Colorado River downstream from Hoover Dam for alternative 1.

8. Using median plotting positions and 72 years of record, the largest recorded event plots at about a 100-year exceedance interval. Since the graphical regulated curve does not have an established shape such as an analytical curve does, additional information is required to extend the curves. Balanced hydrographs developed from the natural unregulated curves at Lees Ferry were the basis for extending the regulated curves.

Year	Flow per month								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Ju
1906	458	382	245	227	245	618	1,263	3,960	5,
1907	730	477	351	289	387	788	1,621	3,155	6,
1908	678	364	267	319	357	669	1,142	1,750	3,
1909	558	375	308	375	309	720	1,192	3,716	7,
1910	737	492	371	361	423	1,391	1,863	3,582	3,
1911	620	427	368	378	438	917	1,002	3,016	4,
1912	1,133	442	353	346	327	538	909	3,749	6,
1913	628	533	305	354	314	524	1,851	3,310	3,
1914	657	538	330	370	401	876	1,605	4,737	6,
1915	955	525	334	304	397	527	1,502	2,493	3,
1916	535	411	343	394	424	1,395	1,813	3,817	4,
1917	1,396	496	369	260	352	507	1,544	3,804	7,
1918	483	447	403	356	374	656	900	2,806	5,
1919	551	496	410	287	317	653	1,427	3,293	2,
1920	368	405	394	407	602	685	981	5,961	6,
1921	528	596	405	414	457	948	935	4,241	8,
1922	463	416	453	351	439	907	1,185	4,757	5,
1923	311	401	400	375	340	449	1,318	3,895	5,
1924	737	646	424	313	507	509	1,669	3,347	3,
1925	370	392	275	262	403	609	1,402	2,562	2,
1926	1,010	609	447	360	354	644	1,640	3,627	4,
1927	443	334	379	337	389	606	1,279	4,208	4,
1928	959	738	444	470	463	756	1,051	4,690	4,
1929	622	576	344	332	346	924	1,721	4,398	5,
1930	950	568	437	299	485	576	1,838	2,291	3,
1931	571	428	289	264	367	431	627	1,509	2,
1932	531	359	253	273	557	675	1,703	4,411	4
1933	355	382	273	273	256	502	534	1,710	4
1934	417	303	334	308	303	365	610	1,555	
1935	188	183	229	255	274	341	708	1,676	4
1936	377	323	266	264	318	464	1,452	4,143	3
1937	369	448	317	200	414	702	1,588	3,965	3
1938	490	389	391	326	355	795	1,690	3,707	5
1939	605	485	411	348	300	811	1,289	3,005	1
1940	343	318	286	262	302	452	786	2,552	1

Notes: See footnotes at end of table.

Table A-1. Estimated natural flow for the Colorado River at Lees Ferry. (1,000 Acre-feet)

Flow per month						Water	
Apr	May	June	July	Aug	Sep	Year total	Apr-July total
1,263	3,960	5,083	2,758	1,410	1,430	18,077	13,064
1,621	3,155	6,119	4,747	1,883	903	21,450	15,642
1,142	1,750	3,132	1,851	1,171	583	12,287	7,880
1,192	3,716	7,375	3,843	1,775	1,451	21,997	16,127
1,863	3,582	3,055	1,307	679	574	14,835	9,808
1,002	3,016	4,097	2,244	911	564	14,982	10,358
909	3,749	6,159	3,155	1,275	639	19,025	13,972
1,851	3,310	3,150	1,931	791	699	14,389	10,241
1,605	4,737	6,293	3,051	1,308	779	20,944	15,685
1,502	2,493	3,663	2,049	748	546	14,044	9,707
1,813	3,817	4,756	2,558	1,826	799	19,072	12,944
1,544	3,804	7,791	4,882	1,525	811	23,737	18,021
900	2,806	5,373	2,244	882	700	15,622	11,323
1,427	3,293	2,593	1,448	843	535	12,854	8,761
981	5,961	6,980	3,086	1,293	619	21,782	17,007
935	4,241	8,477	2,779	1,888	938	22,607	16,433
1,185	4,757	5,733	2,096	1,054	641	18,516	13,790
1,318	3,895	5,104	2,969	1,672	1,013	18,249	13,287
1,669	3,347	3,776	1,589	631	397	14,544	10,381
1,402	2,562	2,845	1,954	1,005	1,186	13,267	8,763
1,640	3,627	4,065	1,891	864	460	15,970	11,223
1,279	4,208	4,054	3,029	1,202	2,124	18,385	12,570
1,051	4,690	4,316	2,191	955	560	17,593	12,249
1,721	4,398	5,481	2,710	2,276	1,778	21,509	14,311
1,838	2,291	3,772	1,595	1,804	707	15,322	9,495
627	1,509	2,059	1,009	613	444	8,611	5,205
1,703	4,411	4,248	2,638	1,255	691	17,594	13,000
534	1,710	4,723	1,825	735	577	12,145	8,792
610	1,555	973	626	479	301	6,573	3,763
708	1,676	4,760	2,145	907	613	12,278	9,289
1,452	4,143	3,407	1,579	1,220	731	14,547	10,582
1,588	3,965	3,004	1,844	773	617	14,241	10,401
1,690	3,707	5,366	2,412	882	1,082	17,882	13,175
1,289	3,005	2,304	960	532	698	11,749	7,558
786	2,552	2,212	893	482	551	9,438	6,443

Year	Flow per month							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1941	720	415	366	356	430	676	1,147	5,394
1942	1,810	913	577	404	396	661	2,928	3,620
1943	346	378	369	345	345	539	1,673	2,580
1944	380	451	379	285	344	515	1,073	3,714
1945	356	383	308	330	359	430	811	3,257
1946	528	435	320	348	314	516	1,175	2,117
1947	430	479	424	265	353	667	884	3,685
1948	820	582	441	377	432	625	1,753	4,129
1949	347	404	350	328	351	695	1,408	3,583
1950	535	482	364	348	395	641	1,312	2,390
1951	390	358	424	308	357	423	601	2,152
1952	421	451	340	491	386	436	2,344	5,655
1953	348	376	374	402	365	466	572	1,381
1954	304	426	343	318	342	394	735	1,850
1955	562	361	290	255	253	591	716	2,053
1956	197	275	335	380	280	524	1,036	2,935
1957	162	304	258	295	331	510	876	2,858
1958	756	838	503	392	537	689	1,614	4,686
1959	306	359	368	306	314	351	492	1,489
1960	545	517	351	290	315	755	1,785	2,095
1961	344	349	265	244	319	373	674	1,738
1962	827	547	371	334	775	548	2,586	4,240
1963	526	446	343	202	371	584	816	1,906
1964	278	338	266	268	263	344	659	2,467
1965	258	325	363	380	369	444	1,421	3,470
1966	836	568	552	455	395	982	1,363	2,628
1967	303	349	371	289	307	590	646	1,791
1968	312	328	239	313	338	524	661	2,216
1969	411	386	321	392	353	572	2,022	3,962
1970	664	514	369	371	347	436	609	3,709
1971	647	514	395	419	448	600	1,394	2,570
1972	588	518	418	434	441	863	855	2,138
1973	1,099	607	386	449	415	894	1,388	4,752
1974	390	452	380	385	378	814	977	3,674
MIN	162	183	229	200	245	341	492	1,381
MAX	1,810	913	577	491	775	1,395	2,928	5,961
MEAN	563	451	358	334	377	632	1,256	3,221

Notes: Reference U.S. Geological Survey station number 938000. Table data as developed on

Table A-1 (Continued)

r	Flow per month Apr	May	June	July	Aug	Sep	Water Year Total	Apr-July Total
6	1,147	5,394	4,620	2,375	1,133	711	18,343	13,536
1	2,928	3,620	4,891	2,003	812	432	19,448	13,442
9	1,673	2,580	3,361	2,020	1,143	625	13,723	9,633
5	1,073	3,714	4,819	2,490	783	361	15,594	12,095
0	811	3,257	3,433	2,424	1,395	516	14,004	9,925
6	1,175	2,117	2,802	1,270	790	474	11,086	7,362
7	884	3,685	3,834	2,614	1,522	790	15,948	11,018
5	1,753	4,129	3,951	1,587	828	387	15,912	11,420
5	1,408	3,583	5,157	2,720	895	437	16,673	12,868
1	1,312	2,390	3,818	1,929	709	428	13,352	9,450
3	601	2,152	3,724	2,070	1,085	520	12,410	8,547
6	2,344	5,655	6,222	2,261	1,170	699	20,875	16,482
6	572	1,381	3,923	1,598	956	398	11,160	7,474
4	735	1,850	1,385	1,143	594	508	8,342	5,113
1	716	2,053	2,367	1,115	851	354	9,766	6,250
4	1,036	2,935	3,533	1,058	634	301	11,488	8,562
0	876	2,858	6,724	4,834	1,951	1,018	20,124	15,293
9	1,614	4,686	4,577	1,219	620	452	16,882	12,095
1	492	1,489	2,804	1,323	695	332	9,138	6,107
5	1,785	2,095	3,230	1,235	522	328	11,968	8,345
3	674	1,738	2,519	853	670	888	9,235	5,784
8	2,586	4,240	3,886	2,411	792	412	17,729	13,123
4	816	1,906	1,822	835	629	749	9,227	5,378
4	659	2,467	3,006	1,591	873	365	10,716	7,723
4	1,421	3,470	5,635	3,719	1,528	898	18,810	14,245
2	1,363	2,628	1,933	951	515	357	11,537	6,876
0	646	1,791	3,659	2,072	827	507	11,712	8,168
4	661	2,216	5,064	1,625	1,429	417	13,464	9,566
2	2,022	3,962	3,044	1,942	799	616	14,819	10,970
6	609	3,709	4,182	1,944	845	1,142	15,132	10,445
0	1,394	2,570	4,592	2,101	811	531	15,020	10,657
3	855	2,138	3,835	1,108	538	469	12,206	7,936
4	1,388	4,752	4,992	2,675	924	597	19,179	13,807
4	977	3,674	3,422	1,420	604	285	13,182	9,494
1	492	1,381	973	626	479	285	6,573	3,763
5	2,928	5,961	8,477	4,882	2,276	2,124	23,737	18,021
2	1,256	3,221	4,161	2,093	1,021	667	15,135	10,731

le data as developed on 13 April 1977.

Water year	Month							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1906	1,581	1,546	1,619	1,643	625	582	751	966
1907	1,787	1,550	1,623	1,646	696	998	1,203	1,472
1908	1,687	1,550	1,624	1,623	527	510	518	551
1909	568	560	944	1,647	527	768	967	1,212
1910	1,894	1,550	1,623	1,646	527	510	518	551
1911	568	719	1,624	1,647	527	510	518	551
1912	1,585	1,547	1,618	1,642	527	738	903	1,109
1913	1,756	1,550	1,622	1,647	527	510	518	551
1914	568	1,114	1,619	1,647	586	865	1,059	1,306
1915	1,581	1,546	1,618	1,643	527	510	518	551
1916	568	610	1,620	1,647	527	554	740	949
1917	2,487	1,550	1,623	1,647	842	1,158	1,362	1,648
1918	1,571	1,550	1,624	1,647	527	510	518	551
1919	707	1,550	1,623	1,646	527	510	518	551
1920	568	560	856	1,649	609	923	1,124	1,376
1921	1,472	1,550	1,623	1,647	695	995	1,202	1,443
1922	1,538	1,546	1,603	1,647	527	655	828	1,033
1923	1,087	1,550	1,624	1,647	527	510	579	781
1924	1,780	1,550	1,622	1,646	527	510	518	551
1925	568	560	1,588	1,559	527	510	518	551
1926	568	606	1,587	1,648	527	510	518	551
1927	568	1,471	1,559	1,648	527	510	518	573
1928	1,995	1,550	1,622	1,646	527	510	590	761
1929	1,251	1,550	1,623	1,647	527	646	823	1,051
1930	1,967	1,551	1,623	1,647	527	510	518	551
1931	568	1,019	1,597	1,569	527	510	518	551
1932	568	560	856	889	527	510	518	551
1933	568	742	1,456	1,645	527	510	518	551
1934	568	560	856	889	527	510	518	551
1935	568	560	856	889	527	510	518	551
1936	568	560	856	889	527	510	518	551
1937	568	560	856	889	527	510	518	551
1938	568	560	856	889	527	510	518	551
1939	568	560	856	889	527	510	518	551
1940	568	560	856	889	527	510	518	551
1941	568	560	856	889	527	510	518	551
1942	568	560	1,625	1,647	527	510	518	583
1943	593	1,527	1,534	1,648	527	510	518	551
1944	568	560	856	1,497	527	510	518	551
1945	568	1,332	1,509	1,648	527	510	518	551
1946	568	560	1,460	1,648	527	510	518	551

Table A-2. Regulated monthly Lake Mead historical inflow adjusted to 1980 conditions for alternative 1.

(1,000 Acre-feet)

Month							Water year total
eb	Mar	Apr	May	June	July	Aug	Sep	
25	582	751	966	1,270	1,707	1,058	1,005	14,353
96	998	1,203	1,472	1,572	2,501	1,987	767	17,802
27	510	518	551	585	1,045	1,012	350	11,582
27	768	967	1,212	1,550	2,260	1,545	1,710	14,258
27	510	518	551	585	1,045	1,012	350	11,811
27	510	518	551	585	1,045	1,012	350	9,656
27	738	903	1,109	1,422	1,829	1,042	511	14,473
27	510	518	551	585	1,045	1,012	350	11,673
96	865	1,059	1,306	1,611	2,088	1,012	450	13,925
27	510	518	551	585	1,045	1,012	350	11,486
27	554	740	949	1,206	1,489	1,454	575	11,939
32	1,158	1,362	1,648	1,564	3,122	1,038	587	18,628
27	510	518	551	585	1,045	1,012	350	11,490
27	510	518	551	585	1,045	1,012	350	10,624
29	923	1,124	1,376	2,641	1,788	1,012	350	13,456
35	995	1,202	1,443	2,420	1,743	1,489	639	16,918
27	655	828	1,033	1,970	1,046	1,012	350	13,755
27	510	579	781	1,065	1,446	1,244	737	12,797
27	510	518	551	585	1,045	1,012	350	11,696
27	510	518	551	585	1,045	1,012	350	9,373
27	510	518	551	585	1,045	1,012	350	9,507
27	510	518	573	850	1,206	1,012	1,655	12,097
27	510	590	761	1,222	1,166	1,012	350	12,951
27	646	823	1,051	1,702	1,548	1,706	1,504	15,578
27	510	518	551	585	1,045	1,012	350	11,886
27	510	518	551	585	1,045	1,012	350	9,851
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	350	9,509
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	551	585	1,045	1,012	609	8,230
27	510	518	583	2,097	1,045	1,012	350	11,042
27	510	518	551	585	1,045	1,012	350	10,400
27	510	518	551	585	1,045	1,012	350	8,579
27	510	518	551	585	1,045	1,012	350	10,155
27	510	518	551	585	1,045	1,012	350	9,334

Water year	Month							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1947	568	560	856	889	527	510	518	551
1948	568	560	1,625	1,648	527	510	518	551
1949	568	1,262	1,525	1,648	527	510	518	551
1950	1,074	1,551	1,583	1,648	527	510	518	551
1951	568	560	856	1,348	527	510	518	551
1952	568	560	856	1,291	527	510	644	926
1953	1,364	1,548	1,550	1,648	527	510	518	551
1954	568	560	856	958	527	510	518	551
1955	568	560	856	889	527	510	518	551
1956	568	560	856	889	527	510	518	551
1957	568	560	856	889	527	510	518	551
1958	568	560	856	889	527	510	518	551
1959	568	795	1,542	1,648	527	510	518	551
1960	568	560	856	889	527	510	518	551
1961	568	560	856	889	527	510	518	551
1962	568	560	856	889	527	510	518	551
1963	568	560	856	889	527	510	518	551
1964	568	560	856	889	527	510	518	551
1965	568	560	856	889	527	510	518	551
1966	568	560	856	889	527	510	518	551
1967	568	560	856	889	527	510	518	551
1968	568	560	856	889	527	510	518	551
1969	568	560	856	889	527	510	518	551
1970	568	560	856	889	527	510	518	551
1971	568	560	856	1,649	527	510	518	551
1972	568	560	1,526	1,648	527	510	518	551
1973	568	560	856	1,414	527	510	527	749
1974	1,092	1,551	1,624	1,648	527	510	518	551
1975	568	560	1,405	1,649	527	510	518	551
1976	866	1,548	1,625	1,648	527	510	518	551
1977	568	560	856	889	527	510	518	551

Table A-2 (Continued)

Month							Water Year total
Mar	Apr	May	June	July	Aug	Sep	
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	350	9,499
510	518	551	659	1,597	1,012	350	10,727
510	518	551	585	1,045	1,012	350	10,954
510	518	551	585	1,045	1,012	350	8,430
510	644	926	2,680	1,131	1,012	350	11,055
510	518	551	585	1,045	1,012	350	11,208
510	518	551	585	1,045	1,012	540	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	964	1,045	1,012	350	8,350
510	518	551	585	1,045	1,012	350	9,651
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	585	1,045	1,012	609	8,230
510	518	551	974	1,045	1,012	350	9,120
510	518	551	585	1,045	1,012	350	9,400
510	527	749	2,449	1,741	1,012	350	11,263
510	518	551	585	1,045	1,012	350	11,013
510	518	551	585	1,045	1,012	350	9,280
510	518	551	585	1,045	1,012	350	10,785
510	518	551	585	1,045	1,012	609	8,230

Water year	Month							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1906	1,134	1,175	1,143	1,691	1,054	1,168	1,131	1,168
1907	1,366	1,338	1,244	2,152	1,554	1,722	1,347	1,199
1908	1,577	1,236	1,161	1,416	612	869	980	914
1909	489	489	561	1,722	1,554	1,722	1,347	1,199
1910	1,666	1,666	1,312	920	604	1,046	988	930
1911	482	481	623	1,434	887	988	988	930
1912	1,217	1,195	1,183	1,691	1,092	1,722	1,131	948
1913	1,292	1,376	1,142	1,039	945	1,046	986	927
1914	480	480	806	1,722	1,554	1,722	1,408	1,250
1915	1,711	1,405	1,255	1,164	648	867	985	928
1916	479	932	1,117	1,691	1,202	1,168	1,131	928
1917	1,666	1,532	1,135	2,152	1,943	1,722	1,666	1,168
1918	1,098	1,206	1,188	1,168	887	1,046	986	927
1919	480	479	923	1,158	601	868	986	927
1920	480	479	551	1,722	1,610	1,722	1,666	1,168
1921	1,094	1,301	1,129	2,152	1,221	1,722	1,347	1,168
1922	1,165	1,274	1,359	1,691	1,160	1,168	1,467	1,168
1923	995	1,205	1,268	1,275	1,054	1,168	1,131	1,168
1924	1,427	1,468	1,270	911	600	1,046	984	927
1925	479	478	695	1,276	600	867	985	927
1926	479	478	550	1,168	887	1,168	984	927
1927	478	478	550	1,168	1,054	1,168	1,049	927
1928	1,486	1,487	1,204	1,144	1,092	1,168	1,109	926
1929	478	762	1,066	1,691	1,160	1,722	1,131	926
1930	1,666	1,597	1,232	519	600	1,105	984	926
1931	478	478	781	1,163	600	866	984	926
1932	478	478	550	520	600	866	984	926
1933	478	478	549	573	600	866	984	926
1934	478	478	549	520	600	866	984	926
1935	478	478	549	520	600	866	984	926
1936	478	478	549	520	600	866	984	925
1937	475	476	547	519	600	864	982	923
1938	474	474	546	517	598	863	981	922
1939	474	474	476	517	598	863	917	865
1940	405	403	546	517	598	863	981	865
1941	405	403	476	517	598	863	981	921
1942	474	474	546	1,168	773	929	980	921
1943	474	474	546	1,087	598	863	981	921
1944	474	474	546	1,168	860	863	981	921
1945	474	474	546	597	597	863	981	921
1946	474	474	546	1 44	597	863	1,002	921

Table A-3. Monthly releases from Lake Mead based on the historical record adjusted to 1980 conditions for alternative 1.

(1,000 Acre-feet)

Month							Water year total
Mar	Apr	May	June	July	Aug	Sep	
1,168	1,131	1,168	794	848	874	1,560	13,740
1,722	1,347	1,199	1,131	867	1,722	1,666	17,308
869	980	914	773	830	719	627	11,714
1,722	1,347	1,199	1,131	867	1,722	1,666	14,469
1,046	988	930	811	864	746	685	12,238
988	988	930	811	864	746	685	9,919
1,722	1,131	948	811	864	918	1,151	13,923
1,046	986	927	810	862	744	655	11,823
1,722	1,408	1,250	1,131	862	1,722	1,422	14,559
867	985	928	809	861	787	667	12,087
1,168	1,131	928	810	862	1,722	1,302	13,344
1,722	1,666	1,168	1,131	862	1,123	1,167	17,247
1,046	986	927	810	862	744	657	11,579
868	986	927	810	863	744	656	9,495
1,722	1,666	1,168	1,666	863	1,115	1,180	14,222
1,722	1,347	1,168	1,131	863	1,265	1,224	15,615
1,168	1,467	1,168	809	862	1,263	1,169	14,555
1,168	1,131	1,168	809	862	744	656	12,335
1,046	984	927	810	862	744	656	11,705
867	985	927	809	862	744	656	9,378
1,168	984	927	809	862	743	655	9,710
1,168	1,049	927	809	861	743	1,666	10,951
1,168	1,109	926	809	861	743	654	12,683
1,722	1,131	926	809	861	1,012	1,666	13,284
1,105	984	926	809	861	743	654	11,096
866	984	926	809	861	743	654	9,343
866	984	926	809	861	742	654	8,468
866	984	926	809	861	742	654	8,520
866	984	926	809	861	742	654	8,467
866	984	926	808	860	742	654	8,465
866	984	925	808	860	742	654	8,464
864	982	923	804	856	738	659	8,434
863	981	922	745	799	737	649	8,305
863	917	865	744	799	681	591	7,999
863	981	865	744	799	681	590	7,992
863	981	921	802	855	737	648	8,206
929	980	921	802	855	737	648	9,307
863	981	921	802	855	737	648	8,986
863	981	921	802	855	737	648	8,855
863	981	921	802	855	737	648	8,495
863	1,002	921	802	855	737	648	8,963

Water year	Month							
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1947	474	474	546	517	598	863	1,002	921
1948	474	474	546	855	919	988	981	921
1949	474	474	546	1,168	1,054	929	1,049	921
1950	474	474	546	1,198	598	863	981	921
1951	474	474	546	517	598	863	981	921
1952	474	474	546	1,168	1,092	1,168	980	921
1953	474	474	920	1,588	598	863	1,002	921
1954	474	474	546	517	598	863	981	921
1955	474	474	546	517	598	863	981	921
1956	405	403	546	517	598	863	981	921
1957	474	474	546	517	598	863	981	865
1958	405	403	546	517	598	863	981	865
1959	405	403	546	517	598	863	981	921
1960	474	474	546	517	598	863	981	921
1961	474	474	546	517	598	863	981	865
1962	405	403	476	517	598	863	981	865
1963	405	403	476	447	598	863	917	865
1964	405	403	476	447	598	794	917	865
1965	405	403	476	447	598	863	917	865
1966	405	403	476	447	598	863	917	865
1967	405	403	476	517	598	863	917	865
1968	405	403	476	517	598	863	981	865
1969	405	403	476	447	598	863	981	865
1970	405	403	476	517	598	863	981	865
1971	405	403	476	517	598	863	981	921
1972	405	403	546	517	598	863	981	921
1973	474	474	546	1,168	717	1,168	989	922
1974	474	474	893	1,663	945	863	981	921
1975	474	474	546	1,168	1,054	929	1,049	921
1976	474	474	546	1,244	598	863	981	921
1977	474	474	546	517	598	863	981	921

Table A-3 (Continued)

Month						Water year total
Apr	May	June	July	Aug	Sep	
1,002	921	802	855	737	648	8,437
981	921	802	855	737	648	9,200
1,049	921	802	855	737	648	9,865
981	921	802	855	737	648	8,997
981	921	802	855	737	648	8,416
980	921	802	855	737	648	9,865
1,002	921	802	855	737	648	9,882
981	921	802	855	737	648	8,416
981	921	802	855	737	648	8,416
981	921	802	855	737	648	8,276
981	865	744	799	681	590	8,132
981	865	744	799	681	648	8,050
981	921	802	855	737	648	8,276
981	921	802	800	737	648	8,361
981	865	744	799	720	590	8,171
981	865	744	800	681	590	7,923
917	865	743	799	681	590	7,787
917	865	744	799	681	590	7,719
917	865	744	799	681	590	7,788
917	865	744	799	681	590	7,788
917	865	744	799	681	590	7,858
981	865	744	799	681	590	7,922
981	865	744	799	681	590	7,852
981	865	744	799	681	590	7,922
981	921	744	799	681	590	7,978
981	921	802	855	737	648	8,276
989	922	802	855	737	648	9,500
981	921	802	855	737	648	10,256
1,049	921	802	855	737	648	9,657
981	921	802	855	737	648	9,143
981	921	802	855	737	648	8,416

Table A-4. Net average monthly depletions and diversions from the Lower Colorado River.

Month	Net diversions by reach (units of 1,000 acre-feet)				
	Hoover Dam to Parker Dam	Parker Dam to Palo Verde Dam	Palo Verde Dam to Yuma	Yuma to Morelos Dam	Monthly total
Oct	14	38	225	96	373
Nov	10	29	174	52	265
Dec	21	30	180	116	347
Jan	28	38	225	88	379
Feb	35	41	244	154	474
Mar	56	76	450	205	787
Apr	53	81	479	264	877
May	46	83	495	144	768
June	49	88	523	132	792
July	32	91	540	234	897
Aug	24	83	495	157	759
Sep	24	66	392	100	582
Total annual	392	744	4,422	1,742	7,300

Note: Net average monthly depletions and diversions include evaporation, bank storage, diversions, and return flows for average 1980 conditions.

9. The 69 years of natural flow data at Lees Ferry were analyzed based on a Pearson Type III distribution with log transformation of the data (log-Pearson Type III distribution). The mean, standard deviation and the skew coefficient of the station data were computed for durations of 1, 3, 5, 7, and 12 months. Generalized skew coefficients that provided the best fit of the data and resulted in a consistent set of curves were adopted. The analytical curves with data plotted by median plotting positions are shown on plate A-2. Also listed on the plate are the statistics of the natural flow data.

10. BALANCED HYDROGRAPHS. A "balanced hydrograph" is defined herein as a hydrograph that conforms to a specified set of volume-duration values. The volume-frequency curves from plate A-2 were used to provide the volume-frequency values to generate a set of balanced hydrographs. Annual hydrographs for exceedance intervals of 200, 250, 333, 500, and 1,000 years were generated using the mean calendar monthly flows as a pattern hydrograph. The annual hydrographs were depleted to average 1980 conditions and routed through Hoover, Davis, and Parker Dams for the nine alternatives. The routed outflow values were plotted at the same frequency as the inflow balanced hydrographs. This data, shown plotted on plate A-1 for alternative 1, was used to determine the upper end of the frequency curves.

11. The frequency curves developed are based only on main-stem flows from Hoover Dam and do not include any contribution from the tributary drainage area downstream from Hoover Dam. The differences in the curves for reaches are the result of storage in Lake Havasu and net diversion from the river. The maximum 1-month frequency curves for the five reaches of the river for alternative 1 are shown on plate A-3. The same type of relationship holds for the other alternatives. Discharge-frequency values for the maximum 1-month duration and for the five reaches covering the nine alternatives are listed in table A-5.

COLORADO RIVER STORAGE PROJECT SIMULATION MODEL

12. The Colorado River Storage Project (CRSP) Simulation Model is an outgrowth of the experience gained over the years since 1965 in an attempt to duplicate the hand operation studies that were the basis for both the planning and the operating of the Colorado River Storage Project.

Table A-5. Maximum 1-month discharge frequency values in ft^3/s.

Return period in years	Flood control alternative								
	1	2	3	4	5	6	7	8	9
Hoover Dam to Parker Dam									
1,000	62,000	56,700	47,500	100,300	65,400	62,500	50,000	40,000	50,000
500	53,000	46,200	45,000	88,800	62,500	62,500	50,000	40,000	50,000
333	40,000	40,000	45,000	75,200	62,100	52,400	50,000	40,000	45,800
200	40,000	40,000	45,000	56,500	42,900	40,000	45,000	40,000	42,400
100	35,000	35,000	35,000	29,000	35,000	35,000	35,000	28,000	35,000
50	35,000	35,000	35,000	28,600	35,000	35,000	35,000	28,000	35,000
25	31,000	32,000	31,000	28,300	31,000	31,500	31,300	28,000	31,000
10	28,000	28,000	28,000	28,000	28,300	28,000	28,000	28,000	28,300
5	27,100	27,100	27,000	28,000	28,000	27,000	27,300	28,000	28,000
2	18,700	17,800	17,800	18,700	17,700	18,000	17,700	19,000	18,500
Parker Dam to Headgate Rock Dam									
1,000	61,800	56,700	47,500	99,400	64,400	62,500	47,700	39,000	47,700
500	52,300	46,200	44,000	87,800	62,500	62,500	47,700	39,000	47,700
333	39,000	39,000	42,700	74,200	62,100	52,400	47,200	37,700	43,000
200	37,700	37,700	42,200	56,500	42,900	39,000	42,000	37,100	41,400
100	32,100	32,300	32,300	28,000	32,100	32,300	32,300	28,000	32,000
50	32,000	32,000	32,000	28,000	32,000	32,000	32,100	28,000	32,000
25	29,000	29,000	28,500	27,800	30,000	29,000	28,500	27,000	28,000
10	26,300	26,000	25,500	26,100	26,300	25,700	25,700	26,000	26,300
5	24,400	24,400	24,300	24,400	24,300	24,500	24,300	24,800	24,000
2	15,700	15,500	15,000	15,300	15,300	15,700	15,300	15,700	15,300

Note: See footnote at end of table.

Table A-5 (Continued)

Return period in years	Flood control alternative								
	1	2	3	4	5	6	7	8	9
Headgate Rock Dam to Imperial Dam									
1,000	60,300	55,200	46,000	97,900	62,900	61,000	46,500	37,500	46,500
500	50,800	44,700	42,500	86,300	61,000	61,000	46,500	36,500	46,500
333	37,500	37,800	41,500	72,700	60,600	50,900	46,500	36,500	39,900
200	36,500	36,500	41,500	55,000	41,400	37,500	41,300	36,500	39,900
100	31,500	31,600	31,600	26,700	31,400	31,500	31,500	26,700	31,400
50	31,400	31,400	31,500	26,500	31,300	31,300	31,500	26,600	31,400
25	28,500	28,000	27,700	26,400	28,500	28,300	28,000	25,500	27,300
10	25,000	24,700	24,400	25,000	25,000	24,500	24,900	25,000	25,300
5	23,800	23,700	23,900	23,800	23,700	23,800	23,900	24,300	23,800
2	14,500	14,500	14,400	14,700	14,700	14,700	14,700	15,100	14,700
Imperial Dam to Morelos Dam									
1,000	51,500	46,400	37,800	89,100	54,100	52,200	42,800	32,800	42,800
500	42,000	35,900	37,800	77,500	52,200	52,200	42,800	32,800	42,800
333	32,800	32,800	37,800	63,900	51,800	42,100	42,800	32,800	38,700
200	32,800	32,800	37,800	46,200	32,600	32,800	36,900	32,800	31,100
100	27,800	27,800	27,900	21,400	27,900	27,900	27,900	21,200	27,700
50	27,700	27,700	27,900	21,400	27,800	27,700	27,800	21,000	27,700
25	27,600	26,000	26,000	20,900	27,000	26,500	26,000	20,700	26,000
10	20,500	20,600	20,600	20,700	20,700	20,700	20,700	20,700	20,600
5	20,000	20,000	20,000	20,600	20,500	20,100	20,100	20,100	20,500
2	11,000	11,000	11,000	11,000	10,700	11,300	11,300	11,600	11,300

Note: See footnote at end of table.

Table A-5-(Continued)

Return period in years	Flood control alternative								
	1	2	3	4	5	6	7	8	9
	Immediately downstream from Morelos Dam								
1,000	47,800	42,600	36,400	86,900	51,900	48,400	41,400	31,400	41,400
500	39,800	32,100	36,400	75,300	48,400	48,400	41,400	31,400	41,400
333	31,400	31,400	36,400	61,700	48,100	38,400	41,400	31,400	37,300
200	31,400	31,400	36,400	42,500	28,900	31,400	34,100	31,400	28,900
100	26,500	26,500	26,500	20,600	26,500	29,000	26,500	21,000	26,500
50	26,500	26,300	26,500	20,500	26,400	26,400	26,400	20,000	26,500
25	26,500	26,300	26,500	20,000	26,400	26,400	26,400	19,700	26,500
10	19,500	19,200	19,300	19,700	19,700	19,500	19,400	19,700	19,700
5	18,500	18,600	18,700	19,700	19,700	18,700	18,700	19,400	19,700
2	9,500	9,500	9,500	9,500	9,500	9,500	10,400	10,200	9,500

Note: The discharge frequency values presented are based upon releases from Lake Meade and do not take into account tributary inflows to the river downstream from Lake Meade.

13. The program performs a synthetic operation for all Colorado River reservoirs for all months in exactly the same way because only a certain number of factors influence the operation of a reservoir. These factors, as given below, are described in the following paragraphs.

- Inflow
- Evaporation
- Bank storage loss
- Minimum allowable content
- Maximum allowable content
- Minimum allowable release (includes flood control, fish and wildlife, etc.)
- Maximum allowable release
- Releases other than those going downstream
- Desired operation

These factors come into the computational procedure directly from values recorded on cards or magnetic tape, constants and equations that are an integral part of the program, or data on cards or tape reworked by the program.

Inflow

14. For Fontenelle, Flaming Gorge, Blue Mesa, Navajo, and Glen Canyon Dams, 1968-modified (virgin flows adjusted to the 1968 level of use in the basin) unregulated monthly flows at site are input and adjusted by the program to the present level of use in the year in the future they are to represent; that is, 1906 = 1978, 1907 = 1979, 1908 = 1980* * *. Morrow Point, Crystal, and Hoover historical side inflows are also input and adjusted by the program for additional depletion, depending on the year in the future they are to represent. Davis average net side inflows are input and used directly in the program without adjustment. Parker average net side inflows are input and adjusted by the program for additional depletions and salvage, depending on the year in the future they are to represent.

Evaporation Losses

15. Net evaporation, computed by the program generally using polynomial equations, is used for all upper basin reservoirs. Lake Mead estimated evaporation is based on an annual rate of 6.5 acre-feet of loss per

exposed acre of water surface. (The net figure used for side inflow, which is based on historical gains and losses below Hoover Dam, takes into account Parker and Davis evaporation losses.)

Bank Storage Losses

16. For all upper basin reservoirs, 10-percent surface storage change is used for bank storage change, with the exception of Glen Canyon where 15-percent is used. For Lake Mead, the net figure used for side inflow takes into account 6-1/2-percent surface storage losses.

Minimum Allowable Content

17. Minimum allowable content, as used in the program, is the minimum powerpool content.

Maximum Allowable Content

18. Maximum allowable content is the maximum allowable excluding surcharge.

Minimum Allowable Release

19. All upper basin reservoirs have a pattern of minimum allowable releases that are input data. These releases are based on demands for fish and wildlife, recreation, irrigaton, power, and other requirements. Under certain conditions, the program revises this input pattern to allow for minimum flood control and conservation requirements that are functions of reservoir stages, time of year, and expected inflows. In accordance with regulations published by the U.S. Army Corps of Engineers, Los Angeles District, as revised November 1968 (report) and June 1977 (field agreement), the program computes minimum Lake Mead releases for Hoover Dam flood control during flood control operations. Also, the program can adjust the minimum monthly Glen Canyon releases to enhance fish propagation at Lake Mead.

Maximum Allowable Release

20. Maximum allowable release is computed as the amount of water that can pass through the power plant at 90-percent plant factor. When the power plant is not available for use or when other conditions prevail (that is, flood control operations), the outlet works and spillway can be used to bypass additional water.

Releases Other Than Those Going Downstream

21. Releases from within the reservoirs (Navajo, Mead, and Havasu) are an input item not adjusted by the program.

Desired Operation

22. Input data may impose an operation procedure on the reservoirs of the system. Releases from Parker Dam are always input. If the input data does not specify an operating criteria, the program determines a mode of operation that tends to optimize power production on the reservoirs of the upper basin. The demand for water at Parker Dam, which is adjusted by the program as a function of Lake Mead elevation, governs the operation of the lower basin reservoirs.

23. In actual operation, the program operates up to 14 reservoirs of the system in downstream order. The limitation of machine size allows only 24 sequential months to be stored within the machine; however, by stacking the data, the program is able to process studies of almost unlimited length.

24. Monthly reservoir data is output for each reservoir in the system. An annual summary of reservoir data and power output is printed out at the end of each water supply period.

Application of CRSP Model

25. The CRSP model was applied in two different ways to generate a regulated flow record downstream from Hoover Dam. For discharge-frequency and flood damage determinations, a single sequence consisting of the historical flow record 1906 to 1977 was run under 1980 depletion levels assuming that the reservoir system was full-to-minimum flood control storage requirements at the beginning of the record.

26. For determinations of end-of-period reservoir system storage, hydropower generation, and salinity levels, the CRSP model was run using thirteen 10-year sequences with depletion levels varying as projected from 1977 to 1987. The benefits and costs accruing to water conservation, hydropower, and salinity were then taken as the average results of the 13 sequences. At the start of each sequence run, the reservoir system was assumed to be at the actual 1977 storage levels.

27. An additional important consideration in the application of the CRSP model relates to how the model operates Hoover Dam utilizing a forecasted inflow. The flood control regulations specify that releases will be based on the maximum of the forecast, which is defined as the estimated inflow volume in acre-feet that, on the average, will not be

exceeded 19 times out of 20. The CRSP model computed the maximum forecasted inflow volume for each monthly forecast as the sum of the actual observed inflow volume plus the appropriate error component. The following tabulation summarizes the monthly error components as derived from the Bureau of Reclamation Lake Mead inflow forecast procedure.

Month	Lake Mead inflow (In. of acre-feet)
January	4.0
February	3.4
March	3.2
April	2.5
May	1.5
June	1.0
July	0.3

It should be recognized that the resulting inflow record upon which Hoover flood control releases are based tends to force releases early in the runoff season (say January through March) because the highest error components are in those months. This approach, however, was retained because the alternative of determining maximum, mean, and minimum forecasts for upper Colorado River reservoirs plus Hoover Dam for the entire period of record (1906 to 1977), based on current runoff forecasting techniques, was simply not feasible. Hence, actual operation of Hoover Dam should show that the distribution by month of high flood control releases is more uniform than study simulations indicate.

HYDRAULICS

28. The Hydraulics Section, Los Angeles District, between April 1977 and March 1978, conducted detailed overflow studies for four reaches of the Colorado River in the vicinity of Needles, Parker, Blythe, and Yuma. The hydraulic computer models generally covered the areas between the existing river levees, so that, when the discharge remained between these limits, the results are reliable. For the large flood discharges where flow breaks out of the existing river system, however, the results are approximate and should be used only for economic analysis. Overflow limits were plotted on topographical mapping (where 1 in. = 100 ft.), based on aerial photos taken in July 1977 for the Corps of Engineers. The following paragraphs describe the hydraulic analyses for the four study reaches.

Needles

29. Water-surface profiles and overflow maps for discharges ranging between 20,000 and 100,000 ft^3/s were developed for a 6-mile reach of the Colorado River in the vicinity of Needles, California. (See pl. A-4.) The HEC-2 backwater program was used to develop water-surface

profiles between the existing river levees. The 1977 topographic mapping supplemented the cross sections surveyed by the Bureau of Reclamation in June 1975. To estimate overbank elevations for the very large floods, U.S. Geological Survey (USGS) quadrangle maps were used.

30. The Manning's roughness coefficients were based on field investigations and aerial photos. A channel "n" value of 0.030 was used. Overbank "n" values varied from 0.05 to 0.10. Very high "n" values of 0.20 and 0.25 were used in areas that were heavily obstructed by trailers and other structures.

31. For flood levels below the top of the levee, the starting-water-surface elevations were taken from a Bureau of Reclamation profile developed for this reach of the Colorado River. Elevations from this profile at river mile 243.0 agreed within 0.1 foot with the backwater run from Lake Havasu to the downstream limit of this study reach done by the Bureau's Hydrology Section. It was determined that floodflows would overtop the Arizona levee near river mile 243.9 for discharges of 73,000 and 100,000 ft^3/s. The maximum starting-water-surface elevation was set at 1 foot above the existing levee on the Arizona side of the river.

32. Within the study reach there is one existing bridge at river mile 244.4 and another bridge under construction at river mile 246.1. Because the existing bridge was scheduled to be removed upon completion of the new bridge in July 1978, only the new bridge was considered in the backwater run. Two feet of debris were assumed on each side of the bridge piers.

33. Flood profiles were developed based on the assumption that the water would be contained within the levees. However, the 100,000 ft^3/s discharge overtops the Arizona levee at river mile 248 by about 1 foot. At several other locations the freeboard is less than 0.5 foot. The 100,000 ft^3/s discharge could also probably overtop the levee upstream from the study limit. Once a break occurs, most likely the entire historical flood plain would be inundated because the ground slopes away from the river. The water depths in this wide overflow area were determined by using HEC-2 backwater runs upstream from Topock Gorge. The Arizona levee upstream from river mile 244.9 contains the 73,000-ft^3/s discharge. Studies by the Bureau of Reclamation indicate that flow would not overtop the Arizona levees upstream from the study reach for this discharge.

34. It was determined, however, that a discharge of 73,000 ft^3/s would overtop the California levee at river mile 247.0 and flow into the City of Needles. Therefore, a weir analysis was done to determine the quantity of this flow. Since field investigations showed that the levee had been raised about 1 foot above the elevations shown on the topography, this increase in levee height was included in the breakout analysis. Downstream from the new bridge at river mile 246.1, it was also determined that a discharge of 73,000 ft^3/s would overtop the levee

on the California side. These two breakout flows combined would cause floodwaters to pond in Needles to the same elevation as the water surface in the Colorado River.

35. Between Needles and Topock Gorge, the Colorado River has significant sediment deposition. Although the Bureau of Reclamation carries on a dredging program in this reach, the river channel cannot convey the 73,000- or 100,000-ft^3/s discharges. The study showed that the levee system, under existing channel conditions, would carry 50,000 ft^3/s. The Bureau of Reclamation, however, is not confident that it can maintain a channel capacity greater than 40,000 ft^3/s in this reach during flood stages. The assumption was made, therefore, that discharges greater than 40,000 ft^3/s would break out of the levee causing extensive ponding on the Arizona side of the river. The water-surface elevations were determined by using the result of an HEC-2 backwater run upstream from Topock Gorge.

36. Overflow delineations were made on USGS orthophoto maps, Corps of Engineers topographic maps, and San Bernardino County topographic maps made from 1963 aerial photos. Overflow limits for all floods were plotted on the Corps of Engineers (1-in. = 100-ft-scale) mapping. Overflow limits in the City of Needles plotted on the San Bernardino County (1-in. = 200-ft-scale) topographic maps show that Needles would be flooded by the 73,000- and 100,000-ft^3/s events. The USGS orthophoto maps were used to show delineations for the 50,000-ft^3/s-and-greater discharge events. Overflow limits for selected floods near Needles are shown on plate 2 of the main report.

Parker Strip

37. Water-surface profiles for several flood discharges ranging from 18,000 to 100,000 ft^3/s were developed for a 14.5-mile reach of the Colorado River between Parker and Headgate Rock Dams. (See pl. A-5.) The HEC-2 backwater program was used to do the hydraulic calculations. Cross sections surveyed by the Bureau of Reclamation in January 1971 were supplemented by the 1977 topographic mapping.

38. The channel roughness coefficient was based on the rating table for the gaging station below Parker Dam. HEC-2 backwater model runs for discharges ranging from 10,000 to 24,000 ft^3/s were made using various channel "n" values. Comparison of results of these runs with rating curves permitted selection of an "n" value of 0.034. It was assumed that the "n" value would vary to a minimum value of 0.030 as the stage increased. A constant value of 0.070 was assigned to overbank areas.

39. The Bureau of Reclamation and the Bureau of Indian Affairs have determined that the Headgate Rock spillway gates are capable of maintaining a constant water-surface elevation of 364.4 feet upstream from the dam for all discharges below 100,000 ft^3/s. This elevation was used as the starting-water surface for all the HEC-2 runs.

40. Computed overflow limits for selected flows through Parker Strip are delineated on plate 3 of the main report. Overflow limits for these and other floods are also delineated on 1-in. = 100-ft topographic maps on file in the Los Angeles District.

Blythe

41. An overflow study, conducted for several discharges ranging from 10,000 to 150,000 ft^3/s, covered about 14.4 miles of the Colorado River in the vicinity of Blythe, California. The study reach extended from river mile 116.5 near 22nd Avenue to river mile 130.9 near 2nd Avenue. The HEC-2 backwater program was used to do the hydraulic computations east of the F-canal, whereas overflows from the very large floods were analyzed independently. Field surveys by Corps of Engineers surveyors in overbank areas supplemented the cross sections surveyed by the Bureau of Reclamation in July 1977 and the topographic mapping by the Corps of Engineers in 1977.

42. USGS quadrangle maps were used to extend cross sections in some overbank areas, and also to determine overflow limits of the very large floods.

43. Existing improvements that affect flooding in the Blythe area include extensive river-training structures, bank protection, and levees that are part of an extensive irrigation network in the Palo Verde Valley. In this reach, the Bureau of Reclamation has done the major channel improvement work, which consists primarily of earthfill training structures and bank protection riprap designed to prevent future meandering of the river. These improvements are not flood protection measures, and will be overtopped by large floods. Crisscrossing the overbank area are irrigation canals and drainage ditches. The canals, which are typically 5 feet above the ground, will serve as effective barriers to shallow overbank flooding. Drainage ditches typically have minimal capacity at road crossings, and therefore, have little ability to convey floodflows.

44. The Manning's roughness coefficients were based on field investigations. A channel "n" value of 0.030 was used. Overbank "n" values range from 0.05 in cultivated areas to 0.10 in heavy brush areas.

45. Starting-water-surface elevations were determined using the normal-depth (slope-area) method. The backwater run was started at river mile 113.7, which is about 3 miles downstream from the downstream study limit. This procedure was intended to account for any unknown backwater conditions downstream from the study's starting point. (See pl. A-6.)

46. The cross sections for the HEC-2 model extend from the Arizona bluff line on the left side of the flood plain to the F-canal level on the right overbank. The Bureau of Reclamation, in its flood plain information report, states that the F-canal would effectively contain

the levee design flood of 75,000 ft^3/s. The Corps of Engineers followed this same limit for flows below the levee design flood. For larger floods, the criteria used was that canal levees would fail when the depth of the floodwaters against them exceeded 3 feet.

47. Overflow delineations were made on USGS orthophoto maps and on the Corps topographic maps. These overflow areas accounted for flooding from the Colorado River only, and do not include flooding from the tributaries and local runoff. The backwater run determined that the river channel would contain discharges of 28,000 ft^3/s and below. A discharge of 38,000 ft^3/s would overtop the river training structures in some places, but would not damage any agricultural land or structures. For discharges of 48,000 and 71,000 ft^3/s, flow would leave the channel but would be contained by the F-canal; however, for discharges of 100,000 and 150,000 ft^3/s, the F-canal would fail. The location of where the inital break point would occur is unpredictable, but the levee would probably break at several locations. After breaking, the F-canal floodwaters would travel in a southwesterly direction until they hit another canal. The water would then pond behind the levee until it too was breached. The breakout would continue in this manner across the entire Palo Verde Valley. Depths were assigned based on distance from the river channel, heights of levees, topography, and probability of ponding, which is based on the configuration of levee alinements. The analysis used for overflows that breach the F-canal is deemed adequate for economic studies, but would not be appropriate for flood protection works or flood insurance studies. Delineations of overflow limits for selected floods in the vicinity of Blythe are shown on plate 5 of the main report.

Yuma

48. Water-surface profiles and overflow maps for flows ranging between 5,000 and 150,000 ft^3/s were developed for a 9-mile reach of the Colorado River in the vicinity of Yuma, Arizona. (See pl. A-7.) The HEC-2 backwater program was used to develop water-surface profiles between the existing river levees. Cross sections, provided by the International Boundary and Water Commission and taken in late 1976 and early 1977, were extended using the 1977 Corps of Engineers' topographic mapping. USGS quadrangle maps were used to estimate depths outside the river levees.

49. Extensive stands of well-established vegetation currently exist along the banks of the Colorado River in this reach. Upstream flood control and diversion works have prevented large flows from cleaning out the river channel for many years. Because of the lack of historical gage data for significant flood discharges, judgment is needed in choosing appropriate Manning's roughness coefficients. In this study the channel "n" value was varied with the water depth. The low-flow channel was assigned an "n" value of 0.030. Most of the vegetation is located on a natural bench between the low-flow channel and the natural river bank. For flow depths less than 5 feet on this

bench, the average channel "n" value was varied between 0.035 and 0.050, depending on the thickness of the vegetation. A sensitivity study to test the effect of lowering the average channel "n" value to 0.025 disclosed that the average difference in water-surface elevation was 1.4 feet for discharges of 38,000 and 140,000 ft^3/s. Overbank "n" values were 0.050.

50. The starting-water-surface elevations were taken from a rating curve developed from Bureau of Reclamation water-surface profiles at river mile 18.4. A normal-depth rating curve was also developed at river mile 18.4 and compared with the starting-water-surface elevations. Background runs showed that the difference in starting-water-surface elevations would cause insignificant differences in calculated water-surface elevations at river mile 22.0, the downstream limit of study.

51. Four bridges and a diversion dam influence water-surface computations in the study reach. Bridge pier losses at the Fourth Street and Interstate 8 bridges were modeled from plans supplied by the California Department of Transportation. Plans from the Office of Indian Affairs established elevations and dimensions for the First Street bridge. Field investigation determined the low chord elevation for the clear-span railroad bridge; and the International Boundary and Water Commission supplied data for Morelos Dam. The spillway elevation for this dam was modified in the backwater model to reflect extensive fill that exists downstream from the dam. The downstream fill can cause backwater over the Morelos Dam spillway.

52. Historically there has been significant scour at Yuma narrows for large flood events. Previous studies by the Bureau of Reclamation concluded that there would be significant scour at the narrows and downstream from Morelos Dam for large flood discharges. To estimate an appropriate degree of scour, an HEC-6 sediment transport model was set up for this reach of the Colorado River. Equilibrium conditions were assumed at the upstream study limit at mile 32.9 and at the downstream study limit at mile 18.4 so that there was no scour or deposition at these sections. Morelos Dam served as a channel bed control at river mile 22.09. Three different transport functions--unit stream power, Duboy, and Toffaleti--were compared; and as would be expected, different results were obtained with different sediment transport equations. The general scour trend, however, was the same with each method. The hydrograph used in the computations was based on an average monthly flow of 35,000 ft^3/s with a 3-day-storm hydrograph superimposed. Bed-material gradations were taken from gradations at river miles 32.9 and 21.0, published by the Bureau of Reclamation in "River Control Work and Investigations," December 1976.

53. The amount of scour or deposition in the HEC-6 model varied with discharge and time. In order to estimate an average channel cross section to use for peak-flow backwater computations, bed-profile elevations for 40,000 ft^3/s just prior to the start of the 3-day-storm hydrograph were compared with channel-bed conditions at the peak

discharge of 140,000 ft^3/s. Results obtained from using the three different transport functions for these two points on the hydrograph were then used to determine a smooth-bed profile representing the condition of the bed at the peak of various flood events. Cross sections in the HEC-2 model were redefined to reflect the scoured-bed conditions for discharges above 40,000 ft^3/s.

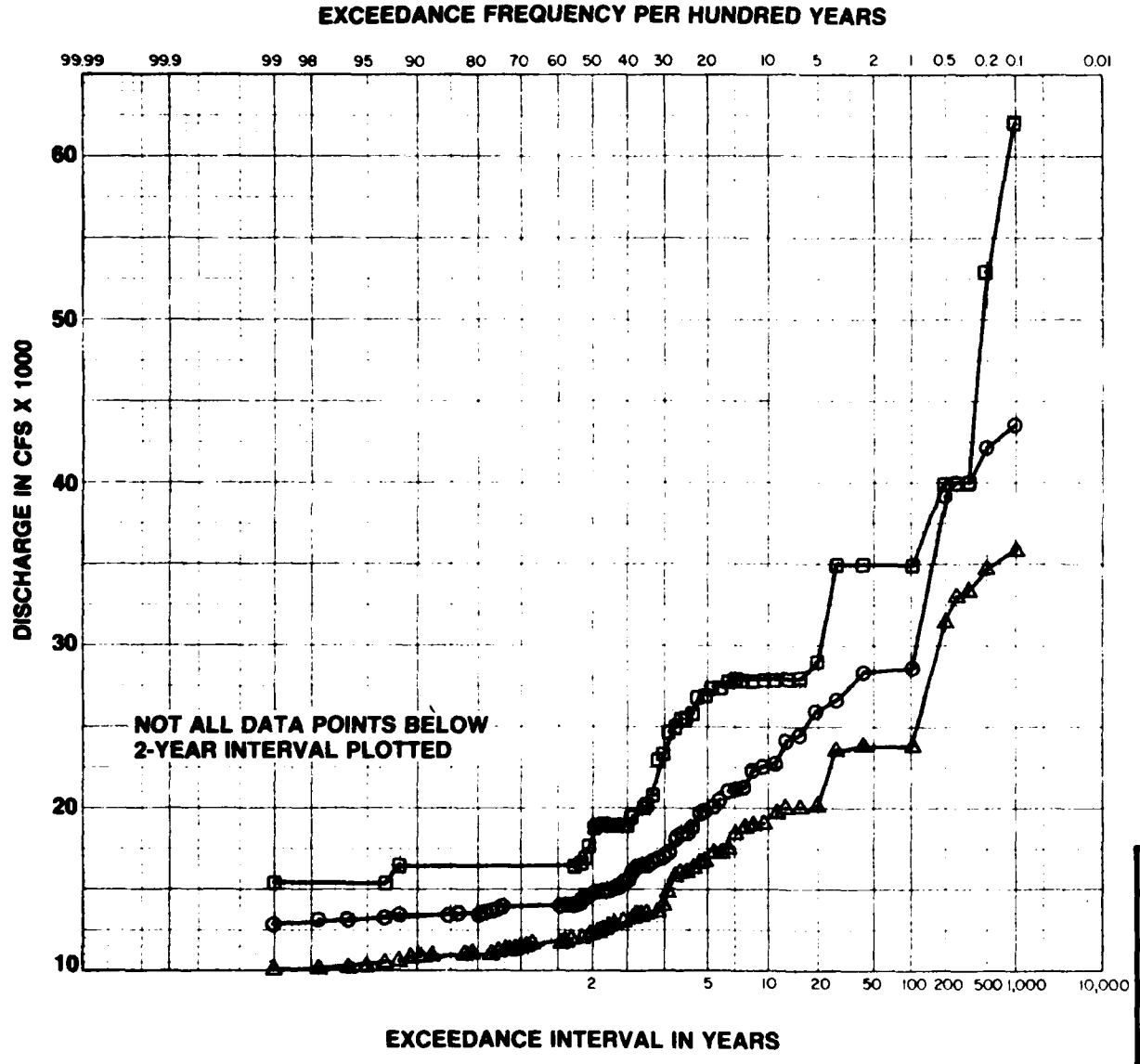
54. Sensitivity studies were conducted on the HEC-6 model to determine the effect of the grain size and sediment input on the water-surface elevations. An increase in D50 from 0.25 to 0.35 mm caused an average increase in the water-surface elevation of 0.5 foot. The computations indicate that, if there is no sediment input into the HEC-6 model, sufficient material would be supplied upstream from station 29.1 from the existing river-bed material so that no significant change in water surface would occur downstream from this station. The maximum change in depth was 1.9 feet at the uppermost section. When the sediment inflow was tripled, this excess sediment would drop out upstream from section 24.68. Water surfaces upstream from the narrows are significantly greater under this condition because of the limitation of scour through the constriction. However, this large sediment inflow is improbable; and if the HEC-6 model were extended upstream, it is expected that the extra sediment load would drop out before reaching the constriction. The sensitivity studies were set up to look at the effects of extreme variations in input parameters. These studies indicate that variations within the expected range of grain diameter and sediment input would have an insignificant effect on water-surface elevations within the study reach.

55. An approximate overflow analysis was made for a discharge of 150,000 ft^3/s, which would breach the existing river levees on both the California and Arizona sides of the river. This analysis is approximate and is intended only for economic purposes. It is reasonable to assume that the levees, once they are overtopped, would fail. Therefore, water-surface elevations in the overbank were assumed to be equal to the water-surface elevation between the levees. By use of a graphical technique, it was determined how much the water-surface elevation would be reduced because of the overbank conveyance. Normal-depth rating curves were developed for various cross sections in the overbank. A rating curve for the area between the levees, taken from the HEC-2 runs, was plotted with the overbank rating curve. The discharges for different water-surface elevations were added graphically to determine a rating curve for the composite cross section. A water-surface elevation for 150,000 ft^3/s was taken from this curve.

56. The West Main Canal acts as a secondary levee after the Yuma levee fails. Since this canal is not designed as a flood control levee, it would be overtopped during the 150,000 ft^3/s event. However, before overtopping, the canal would limit the width of the overbank causing greater depths between itself and the Yuma levee. Composite rating curves were developed for this overbank area; however, it was determined that the elevation of the top of the canal would be the maximum water-surface elevation.

57. The 150,000-ft^3/s event would also cause the lower reservation levee on the California side of the river to be overtopped. In addition, overflow would reach this area from the upstream breakout across the Yuma Main Canal. This area is essentially a backwater or ponding area. Flow must pass back over the levee and return to the channel in order to continue downstream. Backing up the levee is Interstate 8, which would limit the northern extent of flooding. The low point in the lower reservation levee, therefore, would control the minimum water-surface elevation in this area. A minimum water-surface elevation of 134 feet was established; and the maximum water-surface elevation was set equal to the water-surface elevation adjusted for failure of the Yuma levee. The major constriction of the Colorado River at the narrows causes a ponding condition to occur upstream from Yuma. For the 150,000-ft^3/s event, the high water would overtop the levees on both sides of the river and inundate an extensive area. The Yuma Main Canal controls the water-surface elevation in this area. Water would rise to an elevation of 138 feet, which is the low point on this canal.

58. Overflow delineations were made on USGS orthophoto maps and Corps of Engineers topographic maps. Overflow limits were plotted for all flows on the Corps of Engineers (1-in. = 100-ft scale) maps. Overflow limits and average water depths for 150,000 ft^3/s are indicated on the USGS orthophoto maps. Water-surface profiles for the area between the Yuma and lower reservation levees were plotted. Depths at cross-section locations are shown on cross-section plots. The detailed data for Yuma hydraulic studies are on file in the Hydraulics Section of the Los Angeles District. Inundation limits for selected floods are shown on plate 7 of the main report.



GRAPHICAL CURVES

MEDIAN PLOTTING POSITIONS FOR 72 YEARS OF RECORD

- 1 MONTH AVE.
- 6 MONTH AVE.
- 12 MONTH AVE.

ALTERNATIVE I

COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

VOLUME-FREQUENCY CURVES

COLORADO RIVER DOWNSTREAM FROM HOOVER DAM

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE A-1

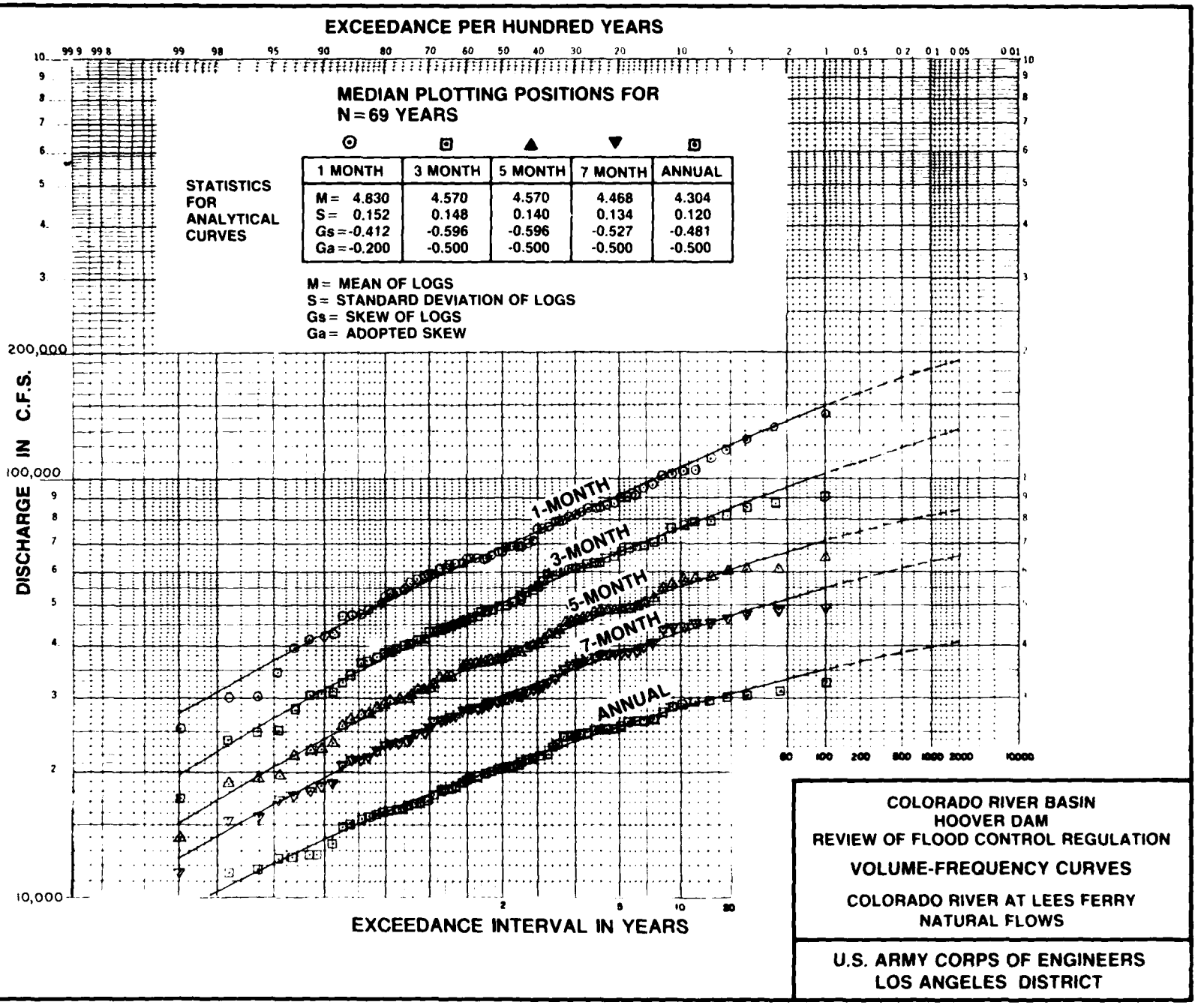

EXCEEDANCE PER HUNDRED YEARS
99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
MEDIAN PLOTTING POSITIONS FOR
N = 69 YEARS
STATISTICS FOR ANALYTICAL CURVES
1 MONTH | 3 MONTH | 5 MONTH | 7 MONTH | ANNUAL
M = 4.830 | 4.570 | 4.570 | 4.468 | 4.304
S = 0.152 | 0.148 | 0.140 | 0.134 | 0.120
Gs = -0.412 | -0.596 | -0.596 | -0.527 | -0.481
Ga = -0.200 | -0.500 | -0.500 | -0.500 | -0.500
M = MEAN OF LOGS
S = STANDARD DEVIATION OF LOGS
Gs = SKEW OF LOGS
Ga = ADOPTED SKEW
DISCHARGE IN C.F.S.
200,000
100,000
10,000
1-MONTH
3-MONTH
5-MONTH
7-MONTH
ANNUAL
2 5 10 20 50 100 200 500 1000 2000 10000
EXCEEDANCE INTERVAL IN YEARS
COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION
VOLUME-FREQUENCY CURVES
COLORADO RIVER AT LEES FERRY
NATURAL FLOWS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE A-2

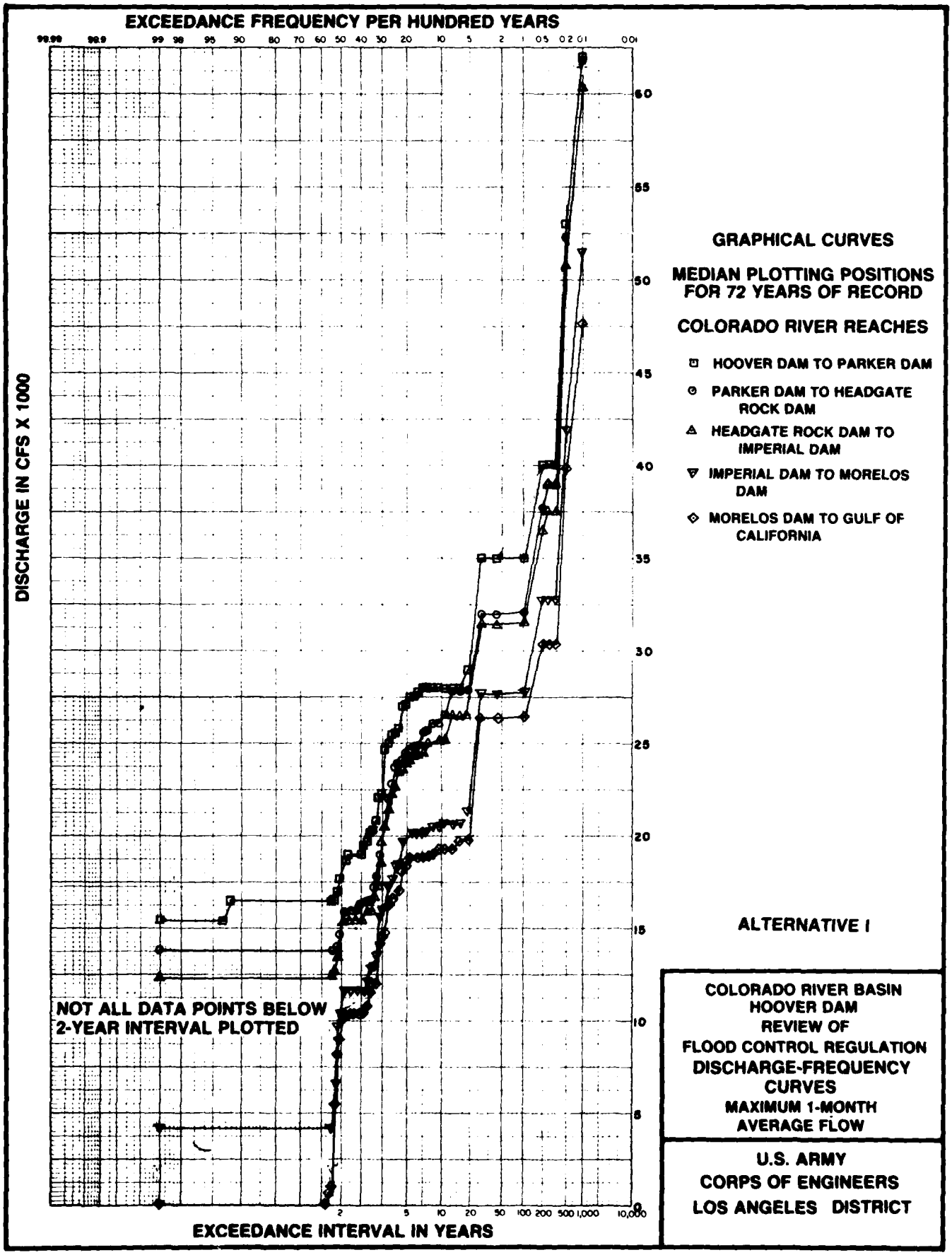
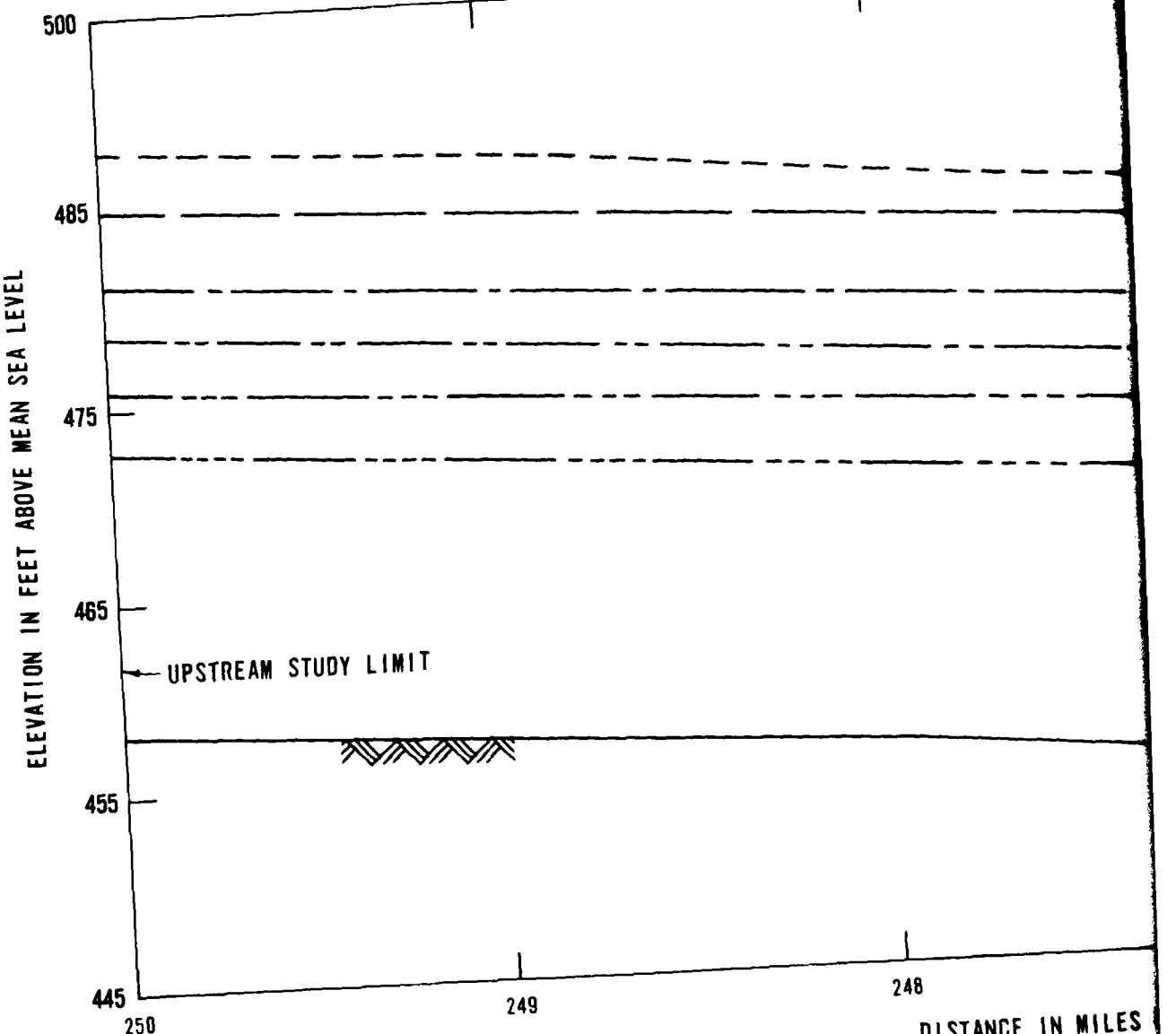
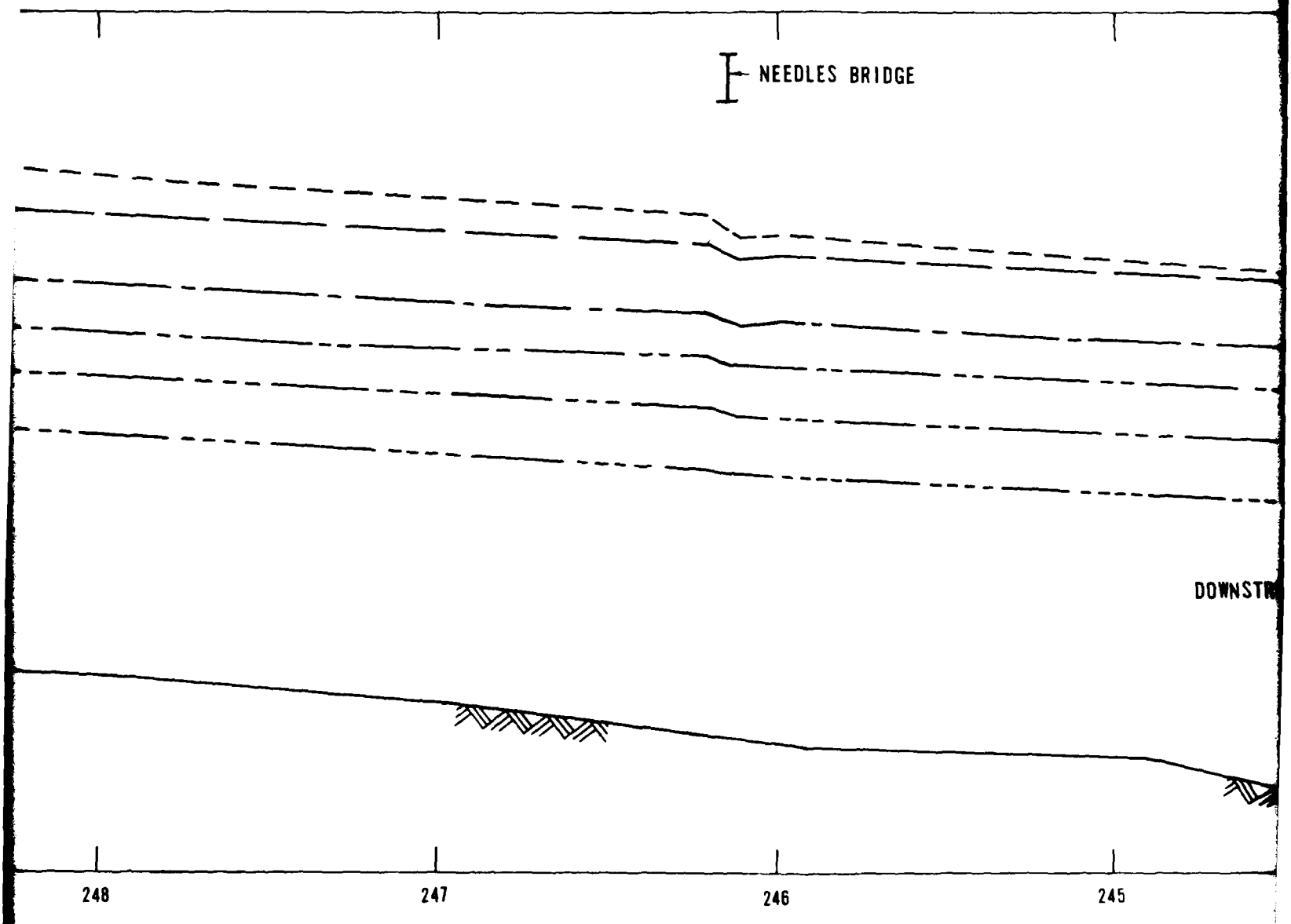
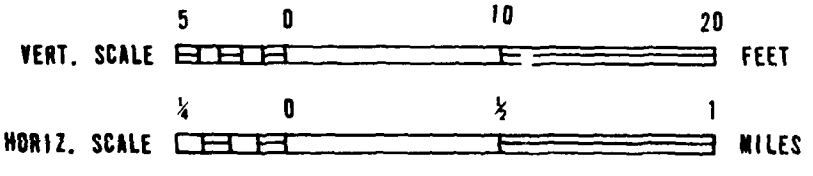

EXCEEDANCE FREQUENCY PER HUNDRED YEARS
99.99 99.9 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.01
DISCHARGE IN CFS X 1000
60
55
50
45
40
35
30
25
20
15
10
5
0
NOT ALL DATA POINTS BELOW 2-YEAR INTERVAL PLOTTED
2 5 10 20 50 100 200 500 1,000 10,000
EXCEEDANCE INTERVAL IN YEARS
GRAPHICAL CURVES
MEDIAN PLOTTING POSITIONS FOR 72 YEARS OF RECORD
COLORADO RIVER REACHES
HOOVER DAM TO PARKER DAM
PARKER DAM TO HEADGATE ROCK DAM
HEADGATE ROCK DAM TO IMPERIAL DAM
IMPERIAL DAM TO MORELOS DAM
MORELOS DAM TO GULF OF CALIFORNIA
ALTERNATIVE I
COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF
FLOOD CONTROL REGULATION
DISCHARGE-FREQUENCY CURVES
MAXIMUM 1-MONTH AVERAGE FLOW
U.S. ARMY
CORPS OF ENGINEERS
LOS ANGELES DISTRICT

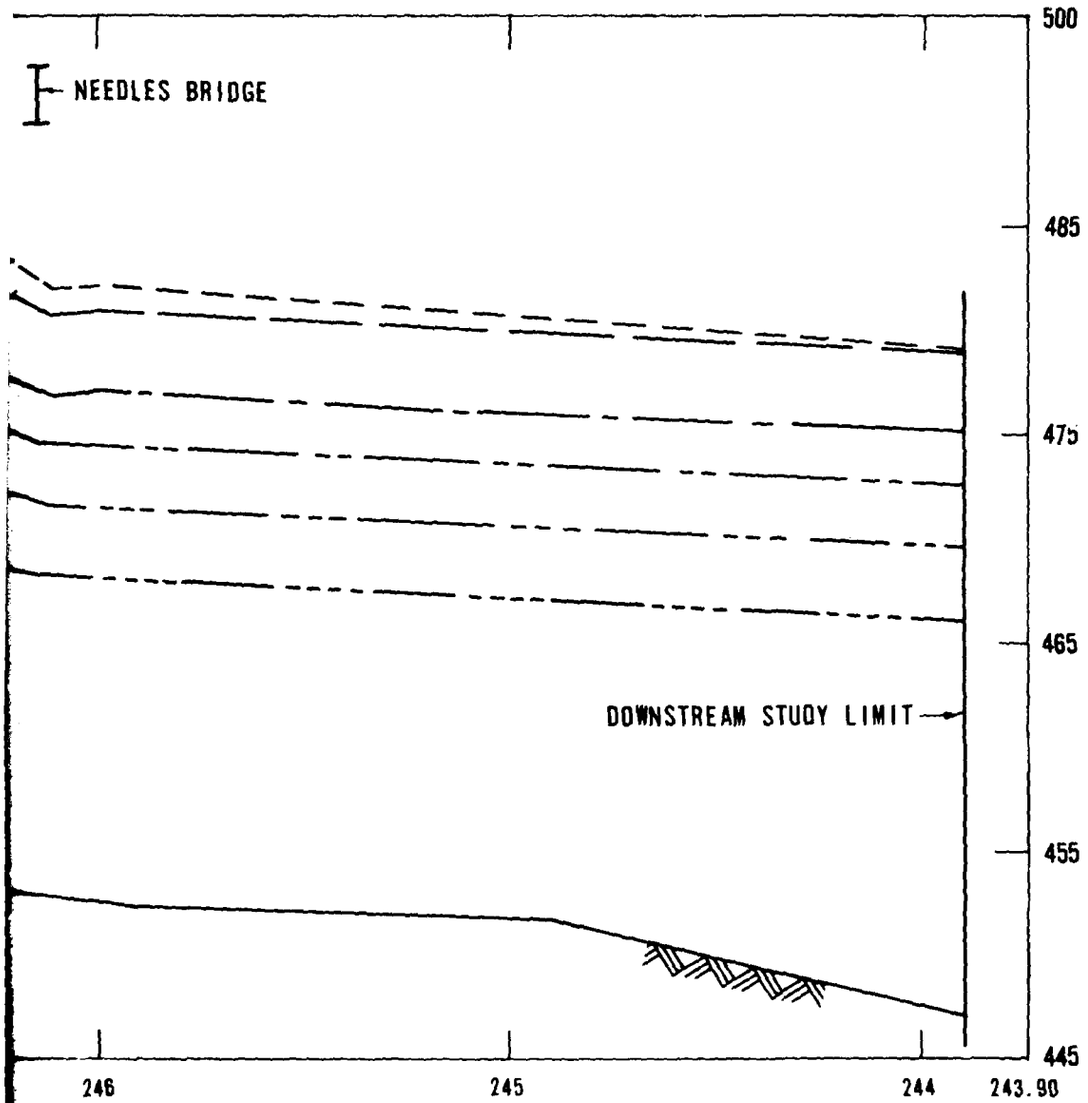
PLATE A-3


500
485
475
465
455
445
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
UPSTREAM STUDY LIMIT
250
249
248
DISTANCE IN MILES
100,000 CFS
73,000 CFS
50,000 CFS
40,000 CFS
30,000 CFS
20,000 CFS
STREAMBED
5
VERT. SCALE
1/4
HORIZ. SCALE



DISTANCE IN MILES UPSTREAM FROM SOUTHERN BOUNDARY U.S. AND MEXICO





. AND MEXICO

FEET

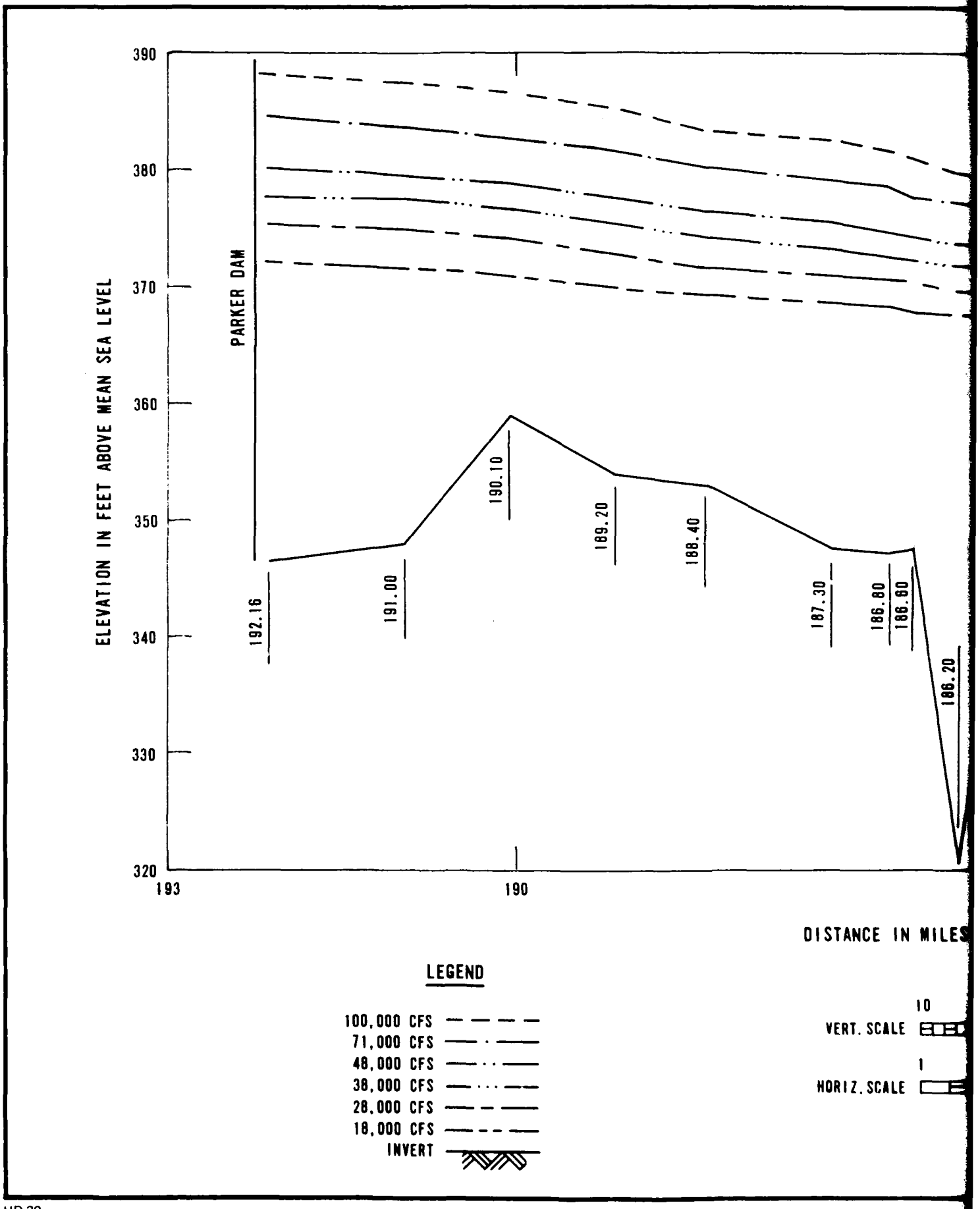
ILES

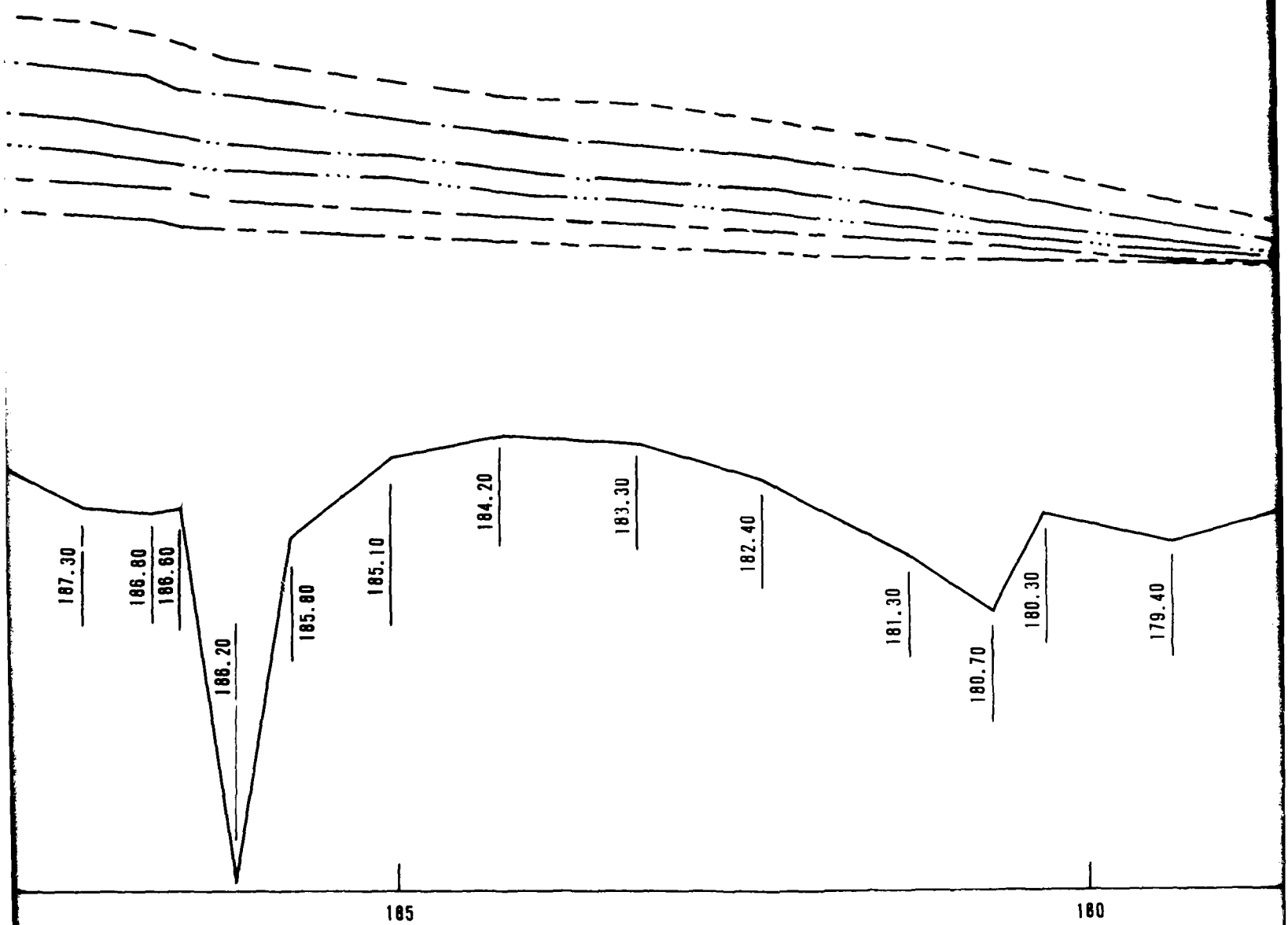
COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

WATER-SURFACE PROFILES
NEEDLES, CALIFORNIA, AREA

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE A-4

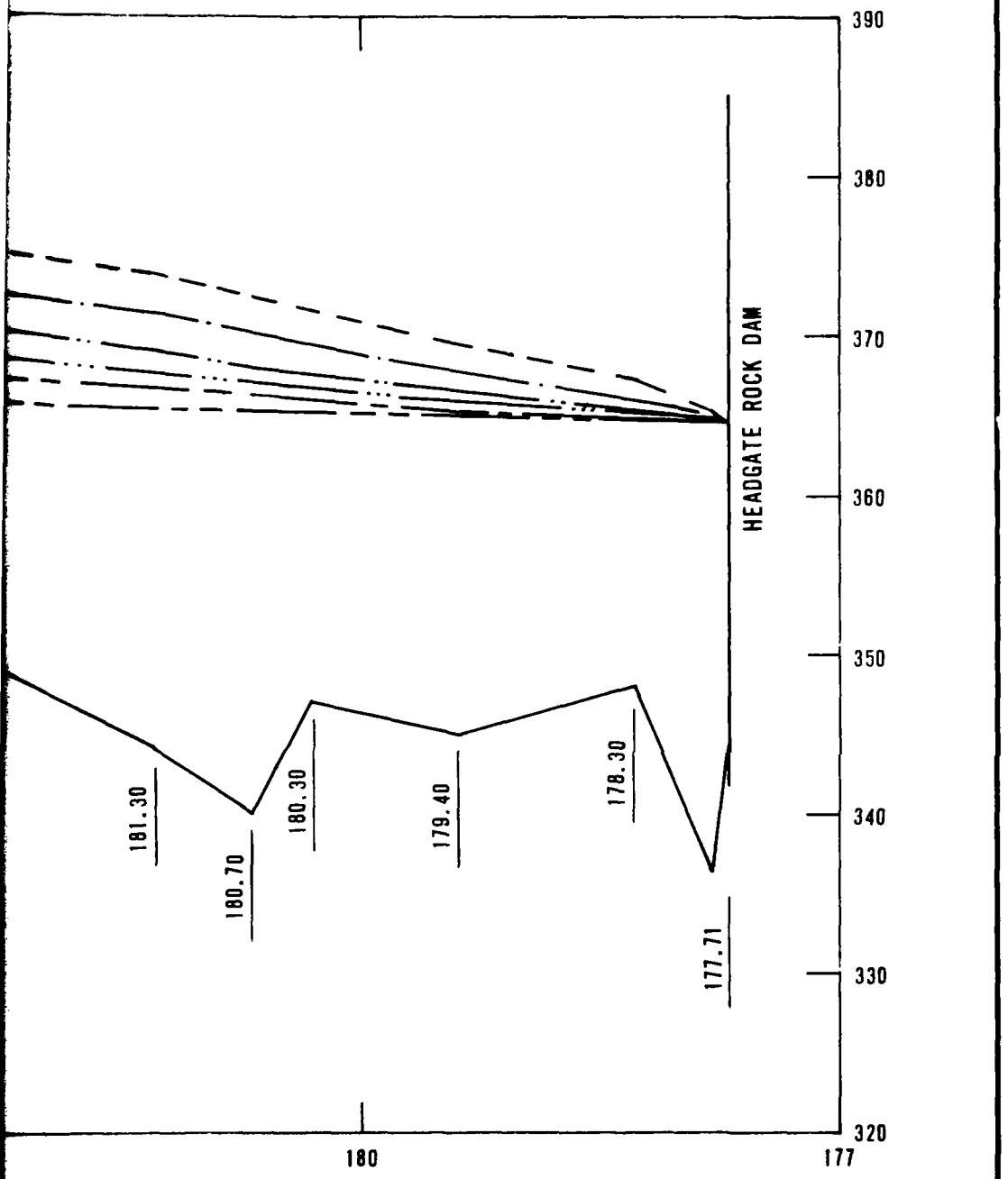

390
380
370
360
350
340
330
320
193
190
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
PARKER DAM
192.16
191.00
190.10
189.20
188.40
187.30
186.80
186.60
186.20
DISTANCE IN MILES
LEGEND
100,000 CFS
71,000 CFS
48,000 CFS
38,000 CFS
28,000 CFS
18,000 CFS
INVERT
10
VERT. SCALE
1
HORIZ. SCALE



DISTANCE IN MILES UPSTREAM SOUTHERN BOUNDARY U.S. AND MEXICO

VERT. SCALE 10 0 10 20 FEET

HORIZ. SCALE 1 0 1 2 MILES

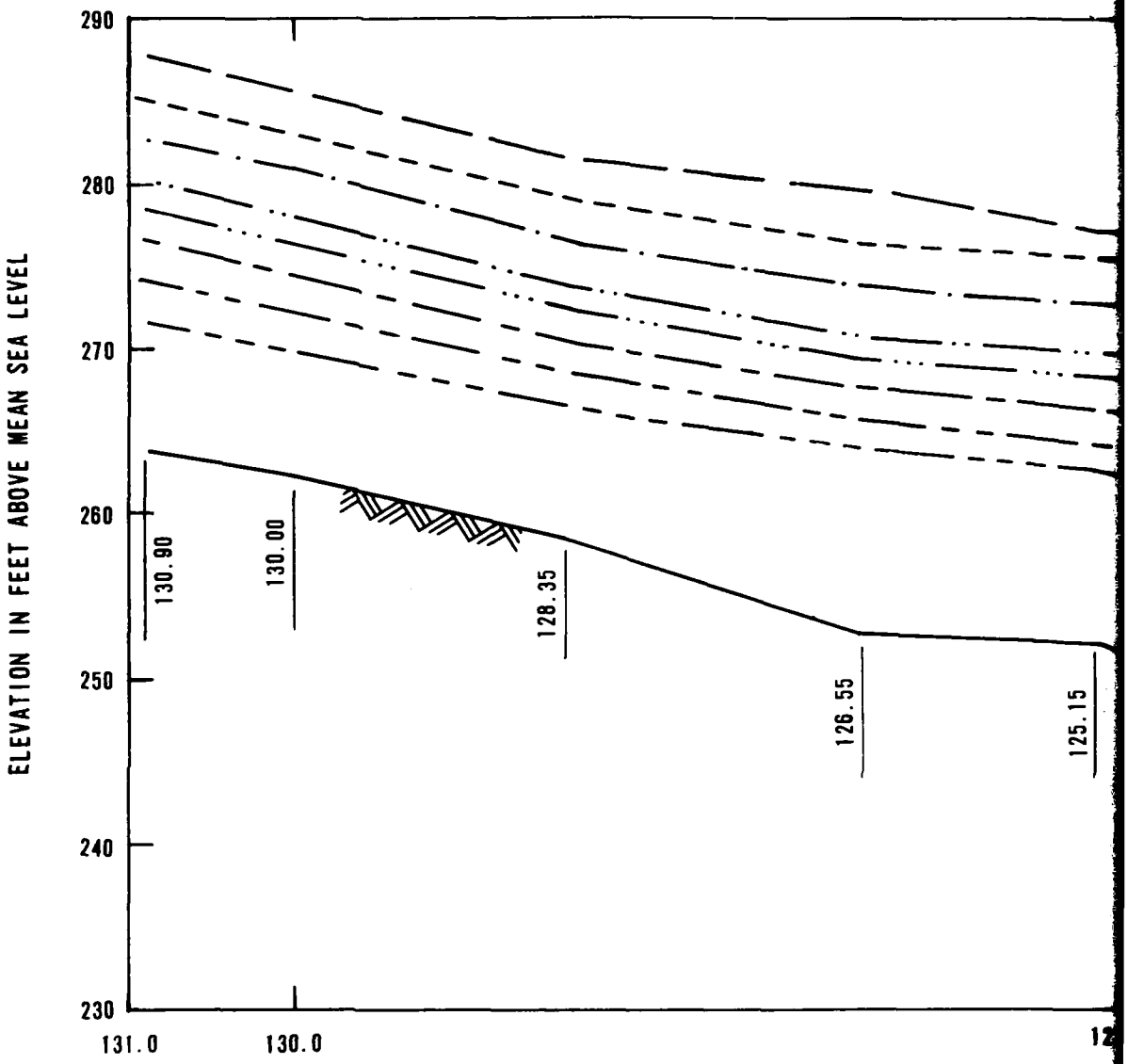


COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

WATER SURFACE PROFILES
PARKER DAM TO HEADGATE ROCK DAM

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE A-5

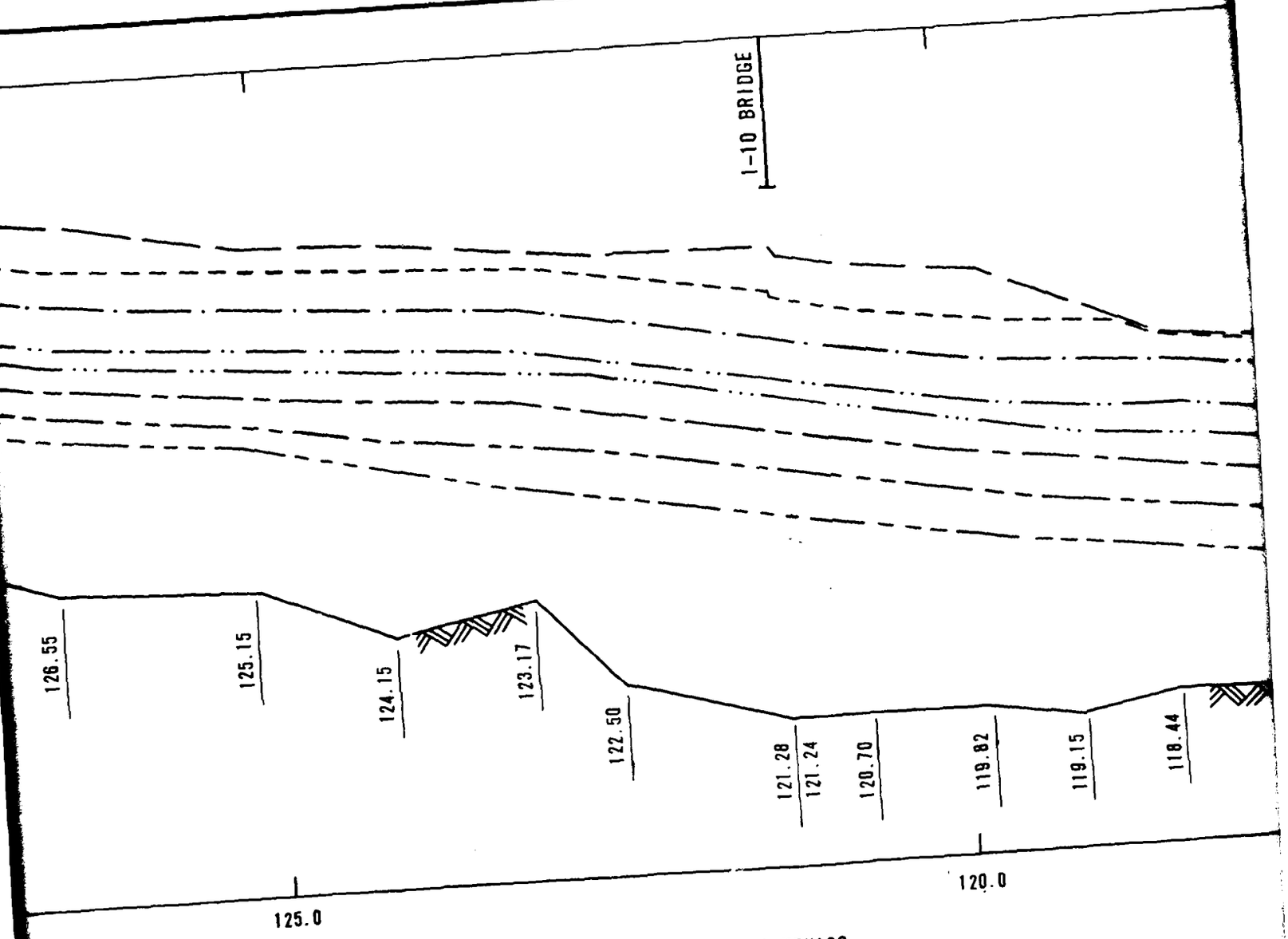


LEGEND

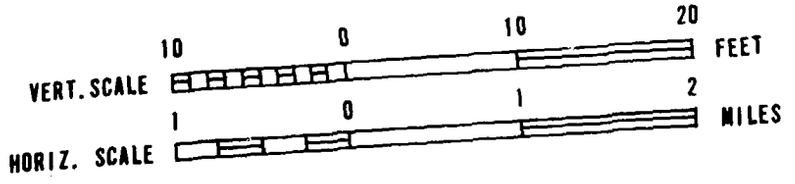
150,000 CFS
100,000 CFS
71,000 CFS
48,000 CFS
38,000 CFS
28,000 CFS
18,000 CFS
10,000 CFS
INVERT

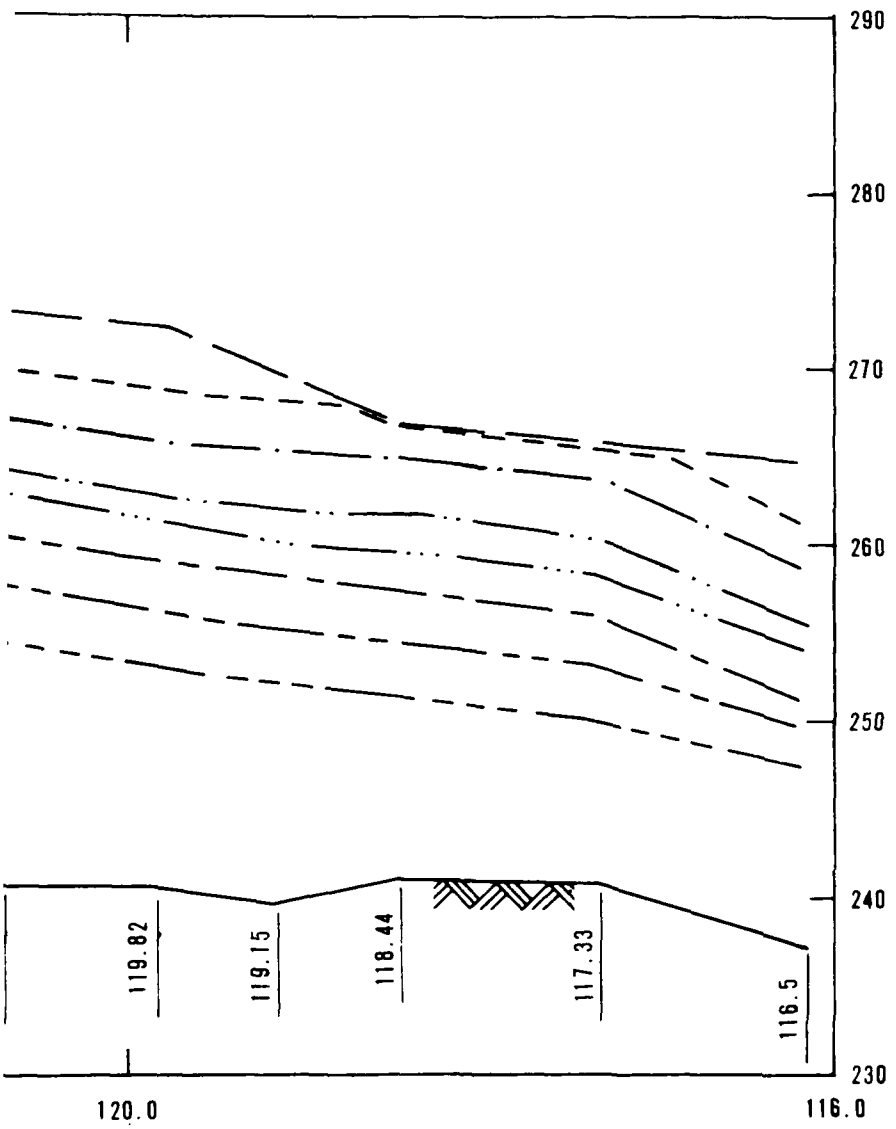
VERT. SCALE

HORIZ. SCALE



DISTANCE IN MILES UPSTREAM SOUTHERN BOUNDARY U.S. AND MEXICO



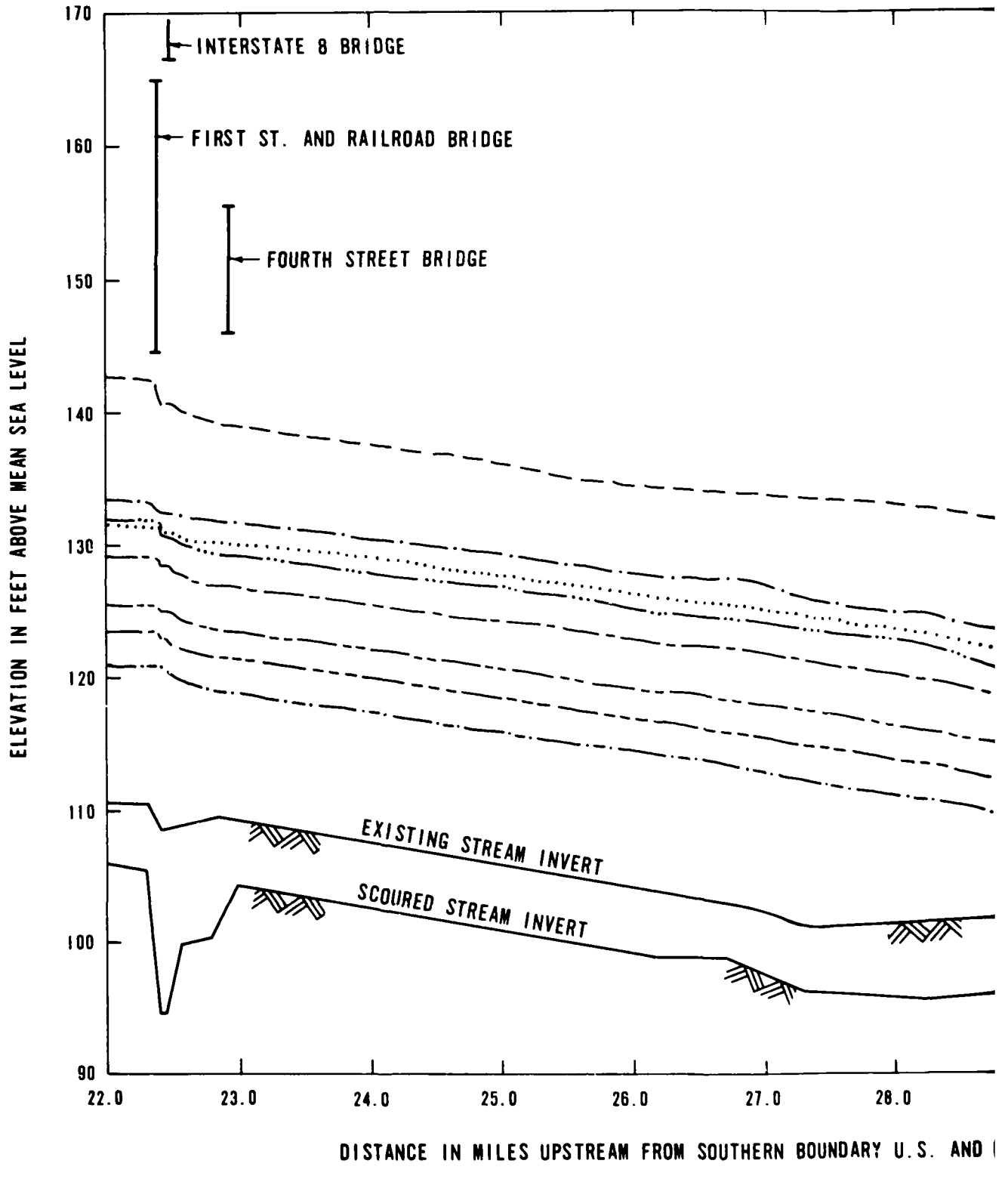


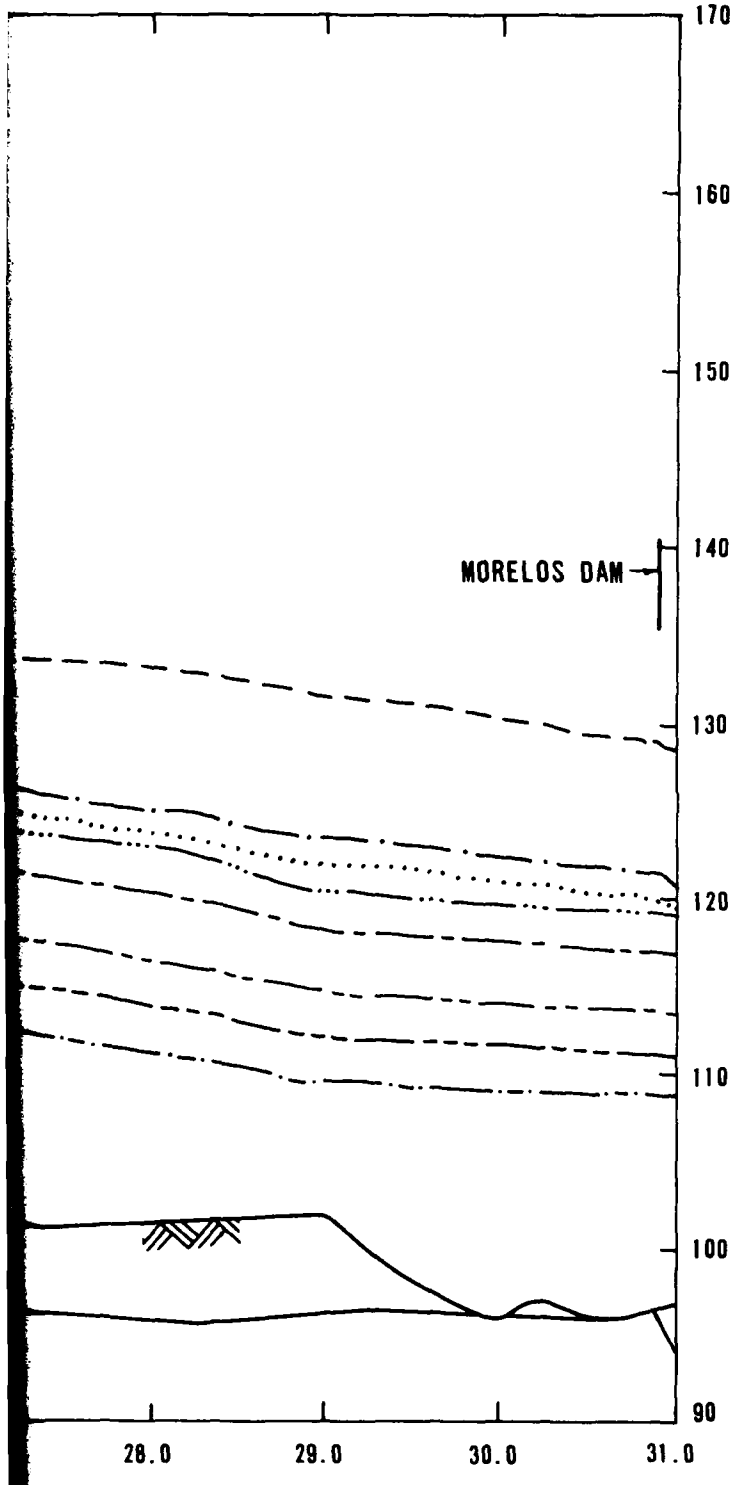
COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

WATER-SURFACE PROFILES
NEAR BLYTHE, CALIFORNIA

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE A-6


170
160
150
140
130
120
110
100
90
INTERSTATE 8 BRIDGE
FIRST ST. AND RAILROAD BRIDGE
FOURTH STREET BRIDGE
EXISTING STREAM INVERT
SCOURED STREAM INVERT
ELEVATION IN FEET ABOVE MEAN SEA LEVEL
22.0
23.0
24.0
25.0
26.0
27.0
28.0
DISTANCE IN MILES UPSTREAM FROM SOUTHERN BOUNDARY U.S. AND



OUNDARY U.S. AND MEXICO

LEGEND

150,000 CFS
71,000 CFS
61,000 CFS
38,000 CFS
28,000 CFS
16,000 CFS
10,000 CFS
5,000 CFS

NOTE:

PROFILES FOR FLOODS ABOVE 38,000 CFS REFLECT SOURCES

VERT. SCALE 5 0 10 20 FEET

HORIZ. SCALE ½ 0 1 2 MILES

COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

WATER-SURFACE PROFILES
AT YUMA, ARIZONA

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

PLATE A-7

Appendix B
EXISTING RIVERWORKS

Appendix B

EXISTING RIVERWORKS

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APPENDIX B

EXISTING RIVERWORKS

1. This appendix describes the riverworks along the Lower Colorado River established by the Bureau of Reclamation to prevent flooding, control stream meandering and sediment deposition, salvage water, stabilize and enhance fish and wildlife habitats, and improve recreation opportunities.

2. For administrative purposes, the Colorado River below Davis Dam has been divided into these 10 divisions:

- Mohave Valley Division (Davis Dam to Topock)
- Topock Gorge Division (Topock to Lake Havasu)
- Havasu Division (Upper Lake Havasu to Headgate Rock Dam)
- Parker Division (Headgate Rock Dam to Palo Verde Diversion Dam)
- Palo Verde Division (Palo Verde Diversion Dam to Taylor Ferry)
- Cibola Division (Taylor Ferry to Imperial Ruins)
- Imperial Division (Adobe Ruins to Adobe Dam)
- Laguna Division (Imperial Dam to Laguna Dam)
- Yuma Division (Laguna Dam to Morelos Dam)
- Limitrophe Division (Morelos Dam to Southern Arizona Border)

The Colorado River Front Work and Levee System in each division is discussed below.

MOHAVE VALLEY DIVISION (DAVIS DAM TO TOPOCK)

3. Scouring of the river channel below Hoover Dam by the clear water released from the reservoir, along with subsequent deposition of the eroded sediment in the backwater zone above Parker Dam, created severe aggradation in the lower Mohave Valley. Prior to 1946, aggradation of the channel in the lower valley caused a rise in average water levels until serious flooding occurred near Needles and there was a threat that conditions would worsen. Channel stabilization was begun in 1949 with initial work consisting of dredging an improved channel between Needles and Topock. This work and associated levee construction eliminated the immediate threat to Needles, but did not in itself provide the river stability between Davis Dam and Topock needed to assure that the problem would not recur. Subsequently, channel dredging, levee construction, and associated work were accomplished upstream from Needles to a point 10 miles below Davis Dam to reduce the pickup and transport of sediment. A settling basin was also built in the river above Topock to trap the sediment arriving from upstream sources and prevent its deposition in Topock Gorge. A hydraulic suction dredge, which is used periodically in the basin to remove this sediment, achieved the needed stability of the channel, and water levels at Needles were brought under control.

4. The levee system in the Mohave Valley Division, constructed of dredge material without riprap as an adjunct to the channel dredging, contributed somewhat to the protection of the adjacent lands. This was an economically responsible position for the development of the lands at that time.

5. More recently, the adjacent lands have undergone accelerated development that may warrant further work on the levee. Related work to improve fish and wildlife habitats and recreational features has also been provided. Topock marsh, which owes its existence to the closure of Parker Dam and the filling of Lake Havasu in 1938, has been encompassed with a dike to maintain water levels at elevation 455 feet above mean sea level. At this level, approximately 4000 acres of open water are available for fisheries and wildlife management. Inlet and outlet structures were constructed to control water apportioned to the Havasu National Wildlife Refuge. The Bureau of Reclamation helped develop the Needles marina and the Park Moabi marina near Topock. These marinas have become more popular each year since their construction.

TOPOCK GORGE DIVISION (TOPOCK TO LAKE HAVASU)

6. Before river stabilization work was begun in the Mohave Valley Division, heavy deposits of sediment were laid down in Topock Gorge and in the upper end of Lake Havasu. While the high-water conditions that existed in Needles prior to 1951 were being corrected, it was recognized that sediment deposits in the Topock Gorge Division were an important factor leading to high-water levels that existed from Topock, Arizona, north beyond Needles. It was also recognized that channel dredging in the river in the Topock Gorge Division would eventually be required. In October 1967, a plan was approved, and work was begun. In June 1968, however, the work was suspended after about 1.7 miles of the upper gorge had been dredged.

HAVASU DIVISION (UPPER LAKE HAVASU TO HEADGATE ROCK DAM)

7. This division covers all of Lake Havasu and the river between Parker and Headgate Rock Dams. Because of the lakes formed behind the dams, and aside from minor protective work at the dams, little need has existed for work under the Colorado River Front Work and Levee System in the division. Although the river does flow in the natural channel for several miles below Parker Dam, no significant work has been required because of the natural channel configuration and rock formation.

PARKER DIVISION (HEADGATE ROCK DAM TO PALO VERDE DIVERSION DAM)

8. Many reaches of the river in the Parker Division are subject to bank erosion, meandering, braiding, and (particularly in the lower part of the division) sediment deposition that makes the river shallow, unstable, and generally of marginal value to water-oriented

developments. The movements of the river have caused large quantities of sediment to be transported to downstream reaches. Valuable riverfront lands have also been lost by bank erosion. Until a sediment trap was built below Imperial Dam, the eroded materials were deposited in Imperial Reservoir, or handled through the All-American Canal Desilting Works and transported downstream to Mexico. Sediment sampling records indicate that the Imperial Reservoir now traps an approximate average of 50 percent of the sediment load, and the Desilting Works and the Laguna Settling Basin are removing the remainder. Channel improvement work, about 14 miles downstream (made urgent by growing land development between Headgate Rock Dam and Alligator Bend) was completed in 1967. The river was stabilized by confining overwide reaches of the river between training structures on stabilized banklines. The river, however, has not been stabilized below Alligator Bend, although a levee was constructed for several miles above Palo Verde Dam on the Arizona side. This levee, designed to protect the adjacent Indian lands up to riverflows of 80,000 ft^3/s, is in good condition.

PALO VERDE DIVISION (PALO VERDE DIVERSION DAM TO TAYLOR FERRY)

9. Except for routine maintenance and repair of constructed features, the channel stabilization in the Palo Verde Division is essentially complete. The work consisted primarily of earthfill training structures and bank riprap designed to prevent future meandering of the river in this division.

CIBOLA DIVISION (TAYLOR FERRY TO ADOBE RUINS)

10. Through much of the Cibola Division, the shallowness of the natural channel was due to sediment deposition. A program to correct channel deficiencies by dredging and by constructing levees was begun in 1964 and completed in 1970. The channel is well-defined, on good alinement, and stabilized. The levee, constructed of the dredge material, is not riprapped.

IMPERIAL DIVISION (ADOBE RUINS TO IMPERIAL DAM)

11. The Imperial Division constitutes the diversion pool and associated backwater areas above Imperial Dam. It is the recipient of the sediment generated in the Parker, Palo Verde, and Cibola Divisions. The sediment load arriving in the Imperial Division is deposited in areas outside the main channel. About 50 percent is deposited on sandbars or in backwater lakes, with the remainder diverted at Imperial Dam. Most of the diverted sediment is removed from the water by the desilting works in the All-American Canal, returned to the river below Imperial Dam, and dredged to permanent dry-land storage areas near the Laguna settling basin just above Laguna Dam.

12. Since Imperial Dam was closed, sedimentation has filled a number of the backwater areas, particularly in the upper end of the division. Other areas have been isolated from the river by natural river-formed dikes. Generally, the remaining deeper backwater areas are in the lower one-third of the division where the water was initially deeper and sediment deposition is less advanced. However, a short reach of the diversion pool immediately upstream from the dam is full of sediment; and occasionally in recent years, it has been difficult to divert water into the headworks of the Gila Gravity Main Canal. Some maintenance dredging immediately upstream from Imperial Dam has temporarily improved these diversions.

LAGUNA DIVISION (IMPERIAL DAM TO LAGUNA DAM)

13. The Laguna Division, which is the empty pool behind Laguna Dam, receives sediment passed by the Imperial sluice gates; and in recent years, has received large quantities of sediment returned from the All-American Canal Desilting Works. Because this created problems associated with Mexican diversions at Morelos Dam, the Bureau of Reclamation constructed a settling basin in the Laguna Division where sediment from upstream sources is trapped and pumped out with a dredge for disposal on dry land.

YUMA DIVISION (LAGUNA DAM TO MORELOS DAM)

14. The river channel extending from Laguna Dam to the upper end of the diversion pool above Morelos Dam was formed by the undiminished natural flow of the river before the dams were constructed. This flow averaged about 20,000 ft^3/s. Substantially larger flows were required to overflow the channel and cause flooding. At the present time, normal flows in this division range from 100 to 1000 ft^3/s, depending on the time of year and location within the division. While the historic riverbed averages 600 feet in width, riverflow currently occupies only about 120 feet. The remaining portions of the riverbed, being at or near the elevation of groundwater, support vigorous growths of vegetation (cattails, cane, arrowweed, salt cedar, mesquite, cottonwood, etc). Above Yuma, these growths are controlled by complete channel reconstruction and continuing programs of vegetative control (mowing or cultivating). A 1969 plan for the Yuma Division anticipated the renovation of the low-flow channel by dredging, reshaping, and lowering the water table under the remainder of the riverbed, and instituting a program of vegetative control. After completion of the work in the upper 6 of the 20 miles of river channel in the division, the work was suspended.

LIMITROPHE DIVISION (MORELOS DAM TO SOUTHERN ARIZONA BORDER)

15. The river in the Limitrophe Division is no longer important as a channel for irrigation water; however, inadequacies have developed in its capacity to convey floodflows. These inadequacies, are being

corrected by work currently under way—primarily the routine clearing of selected portions of the floodway. In this division, the river is an international boundary; therefore, all work, whether planning or construction, is coordinated with the International Boundary and Water Commission.

Appendix C
ECONOMIC EVALUATION OF ALTERNATIVE PLANS

Appendix C

ECONOMIC EVALUATION OF ALTERNATIVE PLANS

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Appendix C

ECONOMIC EVALUATION OF ALTERNATIVE PLANS

1. This appendix presents the economic evaluation of the various alternative regulation schedules for Hoover Dam. One estimate of a plan's performance is economic efficiency. In a project with no real first cost,* the one measure of economic efficiency that has logical validity is net benefits, analyzed at the discount rate established by the Water Resources Council (7-1/8 percent in fiscal year 1980). Maximum net benefits indicate the plan with greatest excess of positive effects (benefits) over negative effects (damages) or the least excess of damages over benefits.

METHODOLOGY

2. Estimates of plan benefits and damages were based upon July 1978 price levels. Each plan was assumed to be operative for 10 years, or until the Central Arizona Project (CAP) is completed and fully operational. Each alternative was evaluated on its annual return with respect to hydropower generation, water diversions, Lake Mead ending storage, average annual flood damages, channel maintenance costs, and salinity (water quality). Recreational impacts were not evaluated because a wide range of release volumes could be made with little or no effect upon the recreational opportunities along the river, and any releases that would preclude water-based recreation of the river itself probably would shift the recreationists onto the lakes (Mead, Mohave, Havasu), with only slight degradation of the recreational experience. Since no "without project" conditions exist, all other alternatives were compared with alternative 1 (the plan that most closely resembles the 1968 operation schedule).

3. Flood damages were estimated by evaluating damages that would occur to 1980 and projected future development under each alternative plan. Damages are a function of type and value of damageable property as well as hydrologic and topographic conditions. Because no recent history of flooding exists for the study area, flood damage estimates were mathematically simulated.

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*Benefit-to-cost ratio and internal rate of return are meaningless with a one-sided equation.

PRESENT LAND USE

4. The area subject to flooding by the lower Colorado River is characterized by long stretches of vacant, nearly inaccessible areas, interrupted by stretches of agricultural areas with urbanization at Needles, Parker, Blythe, and Yuma. Most of the urban lands are in residential uses. The four reaches were selected to encompass the urbanized areas and the agricultural areas immediately adjacent to them. Table C-1 shows the number of units of various types of development within the flood plains that would occur from sustained discharges of various magnitudes.

Table C-1. Land use in flood plains of various-size floods.

Land use	Number of structures inundated				
	At Needles	At Parker Strip	At Blythe	At Yuma	Total for all areas
By flood of 100,000 ft^3/s					
Mobile homes	10	1,588	--	11	1,609
Residential	776	347	211	123	1,457
Commercial/industrial	7	67	--	--	74
Public/semipublic	2	68	--	--	70
Agriculture (in acres)	24,393	4,776	20,164	5,756	55,089
Recreation facilities*		278			278
Total (excluding Ag)	795	2,348	211	134	3,488
Flood of 71,000 ft^3/s (78,000 ft^3/s at Needles)					
Mobile homes	10	737	--	11	758
Residential	243	284	194	65	786
Commercial/industrial	7	47	--	--	54
Public/semipublic	2	64	--	--	66
Agriculture (in acres)	4,124	585	9,065	2,087	15,861
Recreation facilities*		277		--	277
Total (excluding Ag)	262	1,409	194	76	1,941
By flood of 48,000 ft^3/s (50,000 ft^3/s at Needles)					
Mobile homes	0	153	0	11	164
Residential	45	108	88	7	198
Commercial/industrial	--	13	--	--	13
Public/semipublic	--	10	--	--	10
Agriculture (in acres)	1,910	585	--	176	2,671
Recreation facilities*		277			277
Total (excluding Ag)	45	561	88	18	712

Note: See footnote at end of table.

Table C-1 (Continued)

Land use	Number of structures inundated: At Needles	At Parker Strip	At Blythe	At Yuma	Total for all areas
	By flood of 38,000 ft^3/s (40,000ft^3/s at Needles)				
Mobile homes	0	90		11	101
Residential	22	40	--	7	138
Commercial/industrial	--	4	--	--	4
Public/semipublic	--	6	--	--	6
Agriculture (in acres)	--	--	--	176	176
Recreation facilities*	--	232	--	--	232
Total (excluding Ag)	22	372	--	18	401
	By flood of 28,000 ft^3/s				
Mobile homes	--	17	--	--	17
Residential	--	34	--	7	44
Commercial/industrial	--	1	--	--	1
Public/semipublic	--	--	--	--	
Agriculture (in acres)	--	--	--	90	90
Recreation facilities*	--	201	--		201
Total (excluding Ag)	--	253	--	7	260

*Recreation facilities are primarily boat docks that would sustain significant damage with high flows.

PRESENT DAMAGEABLE PROPERTY VALUES

5. Present (1978) values of development in the overflow area were obtained from many sources. Estimates of improvement values for private property were made by (a) sampling development carried on the appropriate county tax assessor's books and adjusting the assessed valuation to market value, (b) consulting knowledgeable real estate brokers for valuation data, and (c) performing field inspections and developing appraisals using such references as the Marshall valuation service. Values were not determined for contents because any damaging release could be preceded by 2 to 4 weeks' warning, which would be ample time for residents to move their belongings to a safe location. It was also assumed that a significant portion of the mobile homes could be relocated with sufficient warning. Damages for the smaller (single width; 45-foot long or less) mobile homes, therefore, were limited to the costs of moving them. Table C-2 lists the values of damageable property within the overflow areas.

Table C-2. Present and future damageable values of structures in flood plain.

Land Use	Value in thousands of dollars									
	At Needles		At Parker Strip		At Blythe		At Yuma		Total for all location areas	
	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989
Flow of 100,000 ft^3/s										
Residential	$15,975	$18,475	$28,951	$31,351	$5,415	$5,415	$3,980	$5,930	$54,321	$61,171
Commercial	325	625	1,601	1,751	--	--	--	--	1,926	2,376
Public/semipublic	140	140	1,770	1,770	--	--	--	--	1,910	1,910
Total	$16,440	$19,240	$32,322	$34,872	$5,415	$5,415	$3,980	$5,930	$58,157	$65,457
Flow of 78,000 or 71,000 ft^3/s*										
Residential	$5,315	$7,815	$16,243	$18,643	$4,800	$4,800	$2,000	$3,950	$28,358	$35,208
Commercial	325	625	1,207	1,357	--	--	--	--	1,532	1,982
Public/semipublic	140	140	1,575	1,575	--	--	--	--	1,715	1,715
Total	$5,780	$8,580	$19,025	$21,575	$4,800	$4,800	$2,000	$3,950	$31,605	$38,905
Flow of 50,000 or 48,000 ft^3/s**										
Residential	$925	$2,225	$4,400	$6,800	$2,200	$2,200	$430	$630	$7,955	$11,855
Commercial	--	--	306	456	--	--	--	--	306	456
Public/semipublic	--	--	795	795	--	--	--	--	795	795
Total	$925	$2,225	$5,501	$8,051	$2,200	$2,200	$430	$630	$9,056	$13,106

Note: See footnotes at end of table.

Table C-2 (Continued)

Land Use	Value in thousands of dollars									
	At Needles		At Parker Strip		At Blythe		At Yuma		Total for all location areas	
	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989
Flow of 40,000 or 38,000 ft^3/s* **										
Residential	$718	$2,018	$2,654	$5,054	--	--	$400	$600	$3,772	$7,672
Commercial			186	336	--	--	--	--	186	336
Public/semipublic			395	395	--	--	--	--	395	395
Total	$718	$2,018	$3,235	$5,785			$400	$600	$4,353	$8,403
Flood of 30,000 ft^3/s										
Residential			$771	$771			$130	$130	$901	$901
Commercial			10	10			--	--	10	10
Public/semipublic			--	--			--	--	--	--
Total			$781	$781			$130	$130	$911	$911

*Needles, 78,000 ft^3/s; other areas 71,000 ft^3/s.
**Needles, 50,000 ft^3/s; other areas, 48,000 ft^3/s.
***Needles, 40,000 ft^3/s; other areas, 38,000 ft^3/s.

FUTURE DAMAGEABLE PROPERTY VALUES

6. Future development in the flood plains was assumed limited to areas that are currently being developed and to areas that are free from flooding by the 100-year release under alternative 1.

7. Depth-damage relationships were used to evaluate the impact of the anticipated flows on development in the flood plain. These relationships, which were developed for each land-use category from historical flood-damage reports, have been verified and adjusted for different hydrologic conditions after each flood in the Los Angeles District. Table C-3 lists the percentage relationships of flood depth versus flood damage for selected points; these relationships, when applied to damageable property, were used to develop unit flood damages.

Table C-3. Percentage relationship of flood depth versus flood damage.

Inside flood depth (ft)	Damage in percent of value of structures			
	Residential structures	Mobile homes	Public & commercial structures	Boat docks*
0.5	5	3.5	7	0
1	10	5	0	0
2	16.5	25	13	0
3	25	59	17	4.5
4	26.8	90	22	15
5	28.5	100	20	30
6	40	100	31	55
7	45	100	36	70
8	50	100	42	90

Note: In addition to the above, agricultural damage is assumed to be $900/acre for 1 foot or more of inundation. Mobile home damage (for those that are 12 feet wide x 45 feet long or smaller) is $400 in relocation costs.

*Depth above normal high water.

8. Table C-4 shows unit damages from floods of various magnitudes. Unit damages for the appropriate flood magnitude and land use were then multiplied by the number of units to calculate estimated damage (table C-5). These estimated damages are representative of the period 1979 to 1989.

Table C-4. Estimated damages per unit from floods of various magnitude from 1979 and 1989.

Land Use	Damage in thousands of dollars									
	At 100,000 ft^3/s		At 78,000 ft^3/s		At 50,000 ft^3/s		At 40,000 ft^3/s		At 30,000 ft^3/s	
	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989
Needles										
Residential.....	$13.2	$12.1	$4.1	$4.0	$0.1	$0.1	$0.6	$0.6	--	--
Mobile homes.....	7.2	7.2	4.7	4.7	-	-	-	-	--	--
Commercial.....	9.0	12.5	6.9	9.6	-	-	-	-	--	--
Public.....	17.5	17.5	14.5	14.5	-	-	-	-	--	--
Agriculture (1 acre).....	1.0	1.0	0.9	0.9	0.9	0.9	-	-	--	--
Parker Strip										
Residential	$7.1	$7.8	$4.4	$5.4	$3.4	$3.9	$3.4	$3.1	$3.3	$3.3
Mobile homes.....	5.9	5.9	3.9	3.9	2.0	2.0	.9	.9	.9	.9
Commercial.....	4.4	4.9	3.5	3.9	2.4	3.1	3.0	3.3	1.0	1.0
Public.....	9.0	9.0	5.6	5.6	12.0	12.0	6.8	6.8	0	0
Agriculture (1 acre).....	0.9	0.9	0.9	0.9	0.9	0.9	0	0	0	0
Recreation facilities.....	0.9	0.9	0.7	0.7	0.4	0.4	0.2	0.2	.1	0.1
Blythe										
Residential.....	$7.9	$7.9	$4.3	$4.3	$1.3	$1.3	--	--	--	--
Mobile homes.....	12.5	12.5	12.5	12.5	12.5	12.5	--	--	--	--
Commercial.....	0	0	0	0	0	0	--	--	--	--
Public.....	0	0	0	0	0	0	--	--	--	--
Agriculture (1 acre).....	0.9	0.9	0.9	0.9	0	0				
Yuma										
Residential.....	$12.8	$15.2	$8.6	$9.8	$7.8	$6.6	$4.6	$3.8	0.5	$0.5
Mobile homes.....	11.8	11.8	11.8	11.8	3.4	3.4	0.3	0.3	0.	0.
Commercial.....	--	--	--	--	--	--	--	--	--	--
Public.....	--	--	--	--	--	--	--	--	--	--
Agriculture (1 acre).....	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.6

Note: Unit refers to a structure or 1 acre (for agriculture).

Table C-5. Estimated 1979 flood damage potential.

Use	Damage in thousands of dollars: At 100,000 (ft^3/s)	At 78,000 (ft^3/s)	At 50,000 (ft^3/s)	At 40,000 (ft^3/s)	At 30,000 (ft^3/s)
Needles					
Commercial	$50	$38	$0	$0	$0
Public	35	29	0	0	0
Residential	10,612	1,009	41	10	0
Mobile homes	72	47	0	0	0
Agriculture	23,696	3,712	1,719	0	0
Total	$34,465	$4,835	$1,760	$10	$0
Parker Strip					
Commercial	$280	$154	$26	$11	$1
Public	614	360	120	41	0
Residential	2,374	1,156	343	208	111
Mobile homes	9,414	2,876	311	77	28
Agriculture	4,299	526	526	0	0
Recreation facilities	235	191	105	55	22
Total	$17,216	$5,263	$1,431	$392	$162
Blythe					
Commercial	$0	$0	$0	$0	
Public	0	0	0	0	
Residential	1,664	840	110	0	
Mobile homes	75	44	19	0	
Agriculture	18,148	8,159	0	0	
Total	$19,887	$9,043	$129	$0	
Yuma					
Commercial	$0	$0	$0	$0	$0
Residential	1,462	522	68	41	18
Mobile homes	130	130	37	3	1
Agriculture	5,180	1,878	158	158	57
Total	$6,772	$2,530	$263	$202	$76
Total for above four reaches					
Commercial	$330	$192	$26	$11	$0
Public	649	389	120	41	0
Residential	16,112	3,527	562	259	129
Mobile homes	9,691	3,097	367	80	29
Agriculture	51,323	14,275	2,403	158	57
Recreational facilities	235	191	105	55	22
Total	$78,340	$21,671	$3,583	$604	$238

9. Damages for each type of land use were summed for each flood in order to determine the damage-discharge relationship for 1979 and 1989 conditions.

10. The damages expected to result from each size flood were weighted by the probability of occurrence of that flood by combining the damage-discharge and discharge-frequency curves. Standard damage-frequency integration techniques were then used to calculate average annual damages.

11. Equivalent annual damages were computed next by summing the present worths of the expected annual damages and applying the capital recovery factor (partial payment series) for a 7-1/8-percent discount rate.

FLOOD DAMAGES BY ALTERNATIVE

12. The impact of each alternative plan was evaluated by using the frequency curve associated with the alternative. The curve was applied to the basic damage-discharge curves. Average annual damages with each alternative were calculated by integrating the frequency curves and the damage-discharge curve. Equivalent annual damages were calculated at a 7-1/8-percent discount rate for a 10-year project life. Average annual and equivalent annual (7-1/8 percent, 10-year) damages with each alternative are shown in table C-6.

13. Flood-damage-reduction benefits attributable to each plan were taken as the difference between the damages with plan 1 and the damages with each of the other alternative plans.

HYDROPOWER VALUATION

14. The Bureau of Reclamation used its Colorado River Storage Project Simulation Model to determine the average annual production of hydropower for each alternative. (See discussion in appendix A, titled "Engineering.") A value of 30 mils ($0.03) per kilowatt hour was assigned to the electrical energy because this price represents the cost of producing the power by alternate means. Table C-7 compares the power generation for the various alternatives.

SALINITY VALUATION

15. Salinity concentrations of Parker Dam releases for each alternative were also determined during historic flow runs of the Bureau of Reclamation's Colorado River Storage Project simulation model. Studies estimating salinity damages have used the salinity rate at Imperial Dam as the point of reference. It was assumed that differences between the salinity rates of average annual Parker Dam releases would be the same at Imperial Dam. The basis for this assumption is that the range of salinity concentrations of Parker releases is quite small (less than 2

mg/l) and the physical processes causing an increase in salinity levels between Parker Dam and Imperial Dam would occur in an identical manner for all the alternatives. The value of direct damages caused by salinity was determined to be $293,400 per part per million per year (1978 dollars). The basis for this valuation is provided in the report "Colorado River Salinity - Economic Impacts on Agricultural, Municipal and Industrial Users," dated December 1980, by the Bureau of Reclamation. Tables C-7, C-8, and C-9 present in part, comparisons by alternative of the estimated salinity projections, salinity differences, and associated costs.

WATER SUPPLY

16. Water supply benefits are of two types: water available for diversion by the Metropolitan Water District (MWD) and the net differential between starting and ending storage in Lake Mead for the 72-year study period. The two components are complementary, in that one can only be increased at the expense of the other. Although it is likely that numerous entities will use more than the scheduled water demand in flood control releases, the MWD diversion of water is the only diversion that can be reliably counted on because its reservoir facilities in southern California are capable of storing water in excess of scheduled demand. Water valuation methodology varies widely from user to user; and because of the complex water entitlement laws, no definite economic conclusion can be drawn from the methodology used by any of the various water users. Water values given by the sellers varied from about $2 to nearly $200 per acre foot, with most values ranging from $20 to $50 per acre foot. For the purpose of this report, a value of $30 per acre foot was assigned to both the ending storage and the diversions. Table C-7 compares the quantities of water conserved for each of the alternative plans.

17. The method used for determining water quantities available for diversion and also ending reservoir system storage was that of simulating the various alternative operating schemes using the Bureau of Reclamation's Colorado River Storage Project Simulation Model for the historical flow record 1905 to 1977.

OPERATION AND MAINTENANCE COSTS

18. A determination was made of operation and maintenance (O&M) costs of the Colorado River Front Work and Levee System associated with each alternative flood control operating plan. The methodology used to quantify the O&M costs associated with each alternative was to establish a relationship between the average monthly flow rate and the corresponding O&M costs. The Bureau of Reclamation's experience in managing the Lower Colorado River showed that O&M activities associated wih channel scour, sediment transport, and bank erosion are proportional to the square of the discharge. O&M cost in 1978 amounted to $1.3 million or $107,000 per month for a normal Davis release of 12,000 ft^3/s. The following tabulation shows the projected relationship of O&M costs to steady monthly releases from Davis Dam.

Flow (ft^3/s)	O&M/Month (Thousands of dollars)
10,000	74
12,000	107
15,000	167
20,000	297
25,000	464
30,000	669
35,000	910
40,000	1,189

O&M costs for each alternative were then determined by multiplying each monthly O&M cost from the tabulation above by each average monthly discharge generated by the Colorado River Storage Project Simulation Model for the 72-year historical record simulation. Average annual O&M cost, as given in table C-7, varied only slightly because the similarity in the pattern of releases caused by the sequence of stepped releases adapted in all plans.

SUMMARY OF BENEFITS AND DAMAGES

19. Table C-7 compares water conserved, power generation, salinity rates, and operation and maintenance costs associated with each alternative plan of operation. Table C-8 compares the net benefits and damages of alternative 1 with those of each of the other alternatives.

IMPACT ANALYSIS

20. This section describes the socioeconomic impacts of the alternative plans. Many of the impacts usually evaluated are not applicable to this study, because all alternatives involve only the operating schedule of current reservoirs. Some of the impacts of the alternatives could be felt long after the estimated 10-year project life. Table C-9 summarizes the economic and social well-being accounts.

SOCIAL IMPACTS

21. Differences in social impacts among the nine alternatives are difficult to discern. Social impacts to be considered might include injury, death, displacement from one's home, and the emotional trauma of heavy individual financial losses. Social impacts normally correlate well with the number of inhabited structures and public use structures flooded. Along the lower Colorado River, the Parker Strip reach contains the most inhabited and public use structures with the greatest vulnerability to flooding and, therefore, would endure most of the social impacts from flooding. Table C-10 lists the number of structures in the Parker Strip reach subject to flooding by flows of 30,000 and 40,000 ft^3/s. Flooding depths would range up to 4 and 6 feet, respectively.

22. One measure for comparing the social impacts of the alternative plans is the frequency with which structures would be flooded. Table C-11 lists by alternative the frequency of 30,000- and 40,000-ft^3/s flows resulting solely from Hoover Dam releases.

23. Based on the frequency of flooding of structures, alternative 4 would have an advantage at 30,000 ft^3/s, but would carry a greater risk of larger floods than all the other alternatives. Alternative 8 has a definite frequency of occurrence advantage at 30,000 ft^3/s and maintains the advantage for larger flows. One disadvantage of alternative 8 not disclosed by the frequency analysis would be greater duration of high flows and larger nonpeak flows. These characteristics would have some negative social impacts, particularly in displacement from homes. Many of the Parker Strip homes are secondary or vacation residences, which would soften the impact of displacement to some extent. The social impacts through the Parker Strip would be indicative of the impacts through all developed reaches, and the analysis can be considered representative of all reaches.

24. Sufficient warning time would be available with all alternatives to prevent injury or death from unexpected flood waves. However, any time larger and faster than normal flows occur, the possibility of a "freak" accident exists. Injury and death can result from careless or reckless behavior or from floodfight operations. All nine alternatives pose this threat, and none of the plans has any apparent safety advantage.

25. Social impacts also could result from shortages of water and hydropower. The impacts, however, would be mostly inconveniences caused by conservation measures requiring reduced uses of these resources for luxury purposes.

								Damage in thousands of
	Alternative 1			Alternative 2			Alternative 3	
Use		1979	Equiv. average 1989	annual*	1979	Equiv. average 1989	annual*	1979
Residential								
Needles	$13	$15	$14.0	$12	$15	$13.5	$11	$13
Parker Strip		36	40	37.5	31	35	32.1	29
Blythe	8	8	8.5	8	8	7.8	7	7
Yuma	4	5	4.7	3	5	4.2	4	6
Total all reaches		$61	$68	$64.7	$54	$63	$57.6	$31
Commercial								
Needles	$0	$0	$0.2	$0	$0	$0.1	$0	$0
Parker Strip		1	1	1.0	1	1	0.9	1
Blythe	1	1	1.4	1	1	1.4	1	1
Yuma	0	0	0.	0	0	0.	0	0
Total all reaches		$2	$2	$2.6	$2	$2	$2.4	$2
Public/semipublic								
Needles	$0	$0	$0.1	$0	$0	$0.	$0	$0
Parker Strip		2	2	1.9	2	2	1.8	2
Blythe	1	1	1.1	1	1	1.0	1	1
Yuma	-	-	-	-	-	-	-	-
Total all reaches		$3	$3	$3.1	$3	$3	$2.8	$3
Recreational facilities								
Parker Strip		$3	$3	$3.5	$3	$3	$2.8	$3
Agriculture								
Needles	$28	$28	$28.0	$27	$27	$26.7	$26	$26
Parker Strip		6	6	5.9	6	6	5.6	6
Blythe	32	32	31.5	28	28	27.9	25	25
Yuma	12	12	11.0	11	11	10.8	11	11
Total all reaches		$78	$78	$76.4	$72	$72	$71.0	$68
Total all damages								
Needles	$41	$44	$42.3	$39	$42	$40.3	$37	$40
Parker Strip		48	52	49.8	41	46	43.2	40
Blythe	42	42	42.5	38	38	38.1	34	34
Yuma	15	17	15.7	15	16	15.2	15	16
Grand total		$146	$155	$150.3	$133	$142	$136.8	$126

* For 10-year span (1979-1989), computed using interest rate of 7-1/8 percent.

Table C-6. Average- and equivalent-annual damages by alternative.

sands of dollars								
ve 3		Alternative 4				Alternative 5		
1979	Equiv. average 1989	annual*	1979	Equiv. average 1989	annual*	1979	Equiv. average 1989	annual*
$13	$12.2	$32	$35	$33.4	$15	$18	$16.8	
29	33	30.7	58	62	59.3	43	47	44.5
7	7.4	16	16	16.5	10	10	9.9	
6	4.6	7	12	9.5	5	7	6.1	
$31	$59	$54.9	$113	$125	$118.7	$73	$82	$77.9
$0	$0.1	$0	$1	$0.5	$0	$0	$0.2	
1	1	0.9	1	2	1.5	1	1	1.3
1	1.3	2	2	2.2	1	1	1.4	
0	0.	0	0	0.	0	0	0.	
$2	$2	$2.3	$3	$3	$4.2	$2	$2	$2.9
$0	$0.	$0	$0	$0.2	$0	$0	$0.1	
2	2	1.8	3	3	2.8	2	2	2.5
1	1.0	2	2	1.6	1	1	1.1	
-	-	-	-	-	-	-	-	
$3	$3	$2.8	$5	$5	$4.6	$3	$3	$3.7
$3	$3	$2.8	$3	3	$3	$4	$4	$3.7
$26	$26.1	$75	$75	$75.	$37	$37	$36.9	
6	6	5.8	14	14	14.3	8	8	7.3
25	25.3	81	81	81.8	44	44	44.1	
11	11.0	20	20	19.3	14	14	13.5	
$68	$68	$68.2	$190	$190	$190.4	$103	$103	$101.8
$40	$38.4	$107	$111	$109.1	$52	$55	$54.	
40	44	42.0	79	84	80.9	94	62	59.3
34	35.0	101	101	102.1	56	26	56.5	
16	15.6	27	32	28.8	19	21	19.6	
126	$134	$131.0	$314	$328	$320.9	$221	$164	$189.4

Use		Alternative 6 1979	Alternative 6 Equiv. average 1989	Alternative 6 annual*		Alternative 7 1979	Alternative 7 Equiv. average 1989	Alternative 7 annual*
Residential								
Needles	$14	$17	$15.6	$12		$14	$13.	$11
Parker Strip		34	38	37.1		29	34	32.3
Blythe	9	9	9.2	7		7	7.6	7
Yuma	4	6	5.2	4		6	5.5	3
Total all reaches		$61	$70	$67.1		$52	$61	$58.4
Commercial								
Needles	0	0	0.2	0		0	0.1	0
Parker Strip		1	1	1.1		1	1	1.
Blythe	1	1	1.4	1		1	1.3	1
Yuma	0	0	0.	0		0	0.	0
Total all reaches		2	2	2.7		2	2	2.4
Public/semipublic								
Needles	0	0	0.1	0		0	0.	0
Parker Strip		2	2	2.2		2	2	2.1
Blythe	1	1	1.1	1		1	.9	1
Yuma	-	-	-	-		-	-	-
Total all reaches		3	3	3.4		3	3	3.0
Recreational facilities								
Parker Strip		3	3	2.9		3	3	3
Agriculture								
Needles	33	33	34.	29		29	30.4	22
Parker Strip		7	7	6.9		7	7	6.4
Blythe	37	37	37.4	25		25	25.3	23
Yuma	12	12	11.9	12		12	12.6	8
Total all reaches		89	89	90.2		73	73	74.7
Total all damages								
Needles	47	50	49.9	41		43	43.5	33
Parker Strip		47	51	50.2		42	47	44.8
Blythe	48	48	48.0	34		34	35.1	32
Yuma	16	18	17.1	16		18	18.1	11
Grand total		$158	$167	$165.2		$133	$142	$141.5

* For 10-year span (1979-1989), computed using interest rate of 7-1/8 percent.

Table C-6 (Continued)

Damage in thousands of dollars						
native 7	Alternative 8			Alternative 9		
. ge annual*	1979	Equiv. average 1989	annual*	1979	Equiv. average 1989	annual*
$11	$12	$11.2	$12	$14	$12.9	
32.3	24	26	24.5	31	35	32.8
6 7	7	6.6	7	7	7.6	
5 3	4	3.8	4	6	3.	
$58.4	$45	$49	$46.1	$54	$62	$56.3
1 0	0	0.1	0	0	0.1	
1.	0	I	0.5	1	1	0.9
3 1	1	1.2	1	1	1.3	
0	0	0.	0	0	0.	
2.4	1	2	1.8	2	2	2.3
0	0	0.	0	0	0.	
2.1	1	1	0.9	2	2	1.8
9 1	1	0.9	1	1	1.	
-	-	-	-	-	-	
3.0	2	2	1.8	3	3	2.8
3	2	2	2.2	3	3	3.3
4 22	22	22.7	27	27	28.1	
6.4	5	5	4.2	6	6	5.9
3 23	23	23.5	25	25	25.4	
6 8	8	8.9	12	12	11.8	
74.7	58	58	59.3	70	70	71.2
5 33	34	34.	39	41	41.1	
44.8	32	35	32.3	43	47	44.7
8 32	32	32.2	34	34	35.3	
1 11	12	12.7	16	18	14.8	
$141.5	$108	$113	$111.2	$132	$140	$135.9

Alternative		Conserved water: Average annual Hoover release (1,000 a-f)	Conserved water: Lake Mead ending storage (1,000 a-f)	Conserved water: Average annual MWD diversions (1,000 a-f)	Power generation, mkWh: Average annual Hoover	Power generation, mkWh: Average annual Lower Basin[a]	Power generation, mkWh: Aver ann syst tot
1	9,767	20,213	921	4,560	6,193	12,252	7,9
2	9,772	20,170	923	4,561	6,195	12,254	7,9
3	9,767	20,218	917	4,561	6,191	12,250	7,9
4	9,766	20,213	920	4,556	6,189	12,248	7,8
5	9,767	20,187	921	4,560	6,193	12,252	7,9
6	9,766	20,218	917	4,562	6,191	12,250	7,9
7	9,766	20,218	917	4,564	6,195	12,250	7,9
8	9,831	19,702	921	4,564	6,195	12,254	7,9
9	9,767	20,213	921	4,560	6,193	12,252	7,9

Note: a-f = acre-foot, mkWh = million kilowatt hours, and p/m = parts per million.

a. Includes Hoover, Davis, and Parker Dams.

b. Includes Upper and Lower Colorado River Dams.

Table C-7. Comparison of conserved water, power generation, and salinity rates for alternatives.

r generation, mkWh		Salinity rates, average annual Parker release			Operation and maintenance costs, average annual
verage annual Lower Basin[a]	Average annual system total[b]	1,000 a-f	1,000 Tons	p/m	($1,000)
12,252	7,902	7,675	715	2,194	
12,254	7,903	7,677	715	2,201	
12,250	7,903	7,677	715	2,201	
12,248	7,891	7,676	716	2,206	
12,252	7,902	7,675	715	2,210	
12,250	7,903	7,677	715	2,208	
12,250	7,903	7,677	715	2,208	
12,254	7,971	7,736	714	2,211	
12,252	7,902	7,675	715	2,210	

r million.

Table C-8. Economic comparison of alternative plans with alternative 1.

Item	Alternative 1	2	3	4	5	6	7	8	9
Plan description									
1. January 1 storage (MAF).....	5.35	5.67	4.50	5.35	5.35	4.50	4.50	7.50	5.35
2. Max. controlled release (1,000 ft^3/s).....	73	73	73	28	35	40	50	73	73
3. Release steps (1,000 ft^3/s).....	19,28,35 40,73	19,28,35 45,73	19,28,35	19,28 35	19,28 35,40	19,28 40,50	19,28,35 40,73	19,28,35 50,73	19,28,35
Relative economic impacts (equivalent annual values in thousands of dollars)									
Hydropower.....	-	$60	$-60	$-120	$0	$-60	$-60	$60	$0
Water									
Lake Mead ending storage...	-	-93	12	0	-56	12	12	-1115	0
MWD diversions.....	-	60	-120	-30	0	-120	-120	0	0
Flood damages.....	-	13	19	-171	-39	-15	8	39	14
Salinity.....	-	0	0	-293	0	0	0	293	0
Operation and maintenance....	-	-7	-7	-12	-16	-14	-14	-17	-16
Relative net benefits.....	-	33	-156	-626	-111	-197	-174	-740	-2

Note: The values displayed in this table represent the relative difference from alternative 1. Minus indicates a decrease in relative benefits afforded by the plan.

Item	1	2	3	
A. Plan description	(See table C-8 for January 1 storage requirements			
B. Impact assessment*				
Water quality*				
Salinity (in ppm) average annual	-	-0.09	0.09	
Salinity cost ($1,000)	-	0	0	-29
Hydropower				
Average annual total				
mkWh	2	-2	-4	0
Value ($1,000)	-	60	-60	-120
Water quantity				
Lake Mead ending storage				
(1,000 a-f) 1979-88 water year	-	-43	5	0
Value ($1,000) @ $30/a-f	-	-93	12	0
Value of diversions 1979-88 water year				
MWD (1,000 a-f)	-	2	-4	-1
Value ($1,000) @ $30/a-f	-	60	-120	-30
Social impacts				
Noise**	No impact	No impact	No impact	No imp
Displacement**	Minor impact as	may be effected by drought and		the in
Aesthetic values**	No impact	No impact	No impact	No imp
Community cohesion**	"	"	"	"
Community growth**	"	"	"	
Economic impact				
Property values**	"	"	"	May value of some property near water.
Tax revenues**	"	"	"	Min property tax because of above.
Public facilities**	"	"	"	No
Public services**	"	"	"	
Regional growth**	"	"	"	
Employment & industry activity**	"	"	"	
Displacement of farms**	"	"	"	

Note: See footnotes at end of table.

Table C-9. Summary of comparison of final alternative plans.

Alternative						
3	4	5	6	7	8	9
l storage requirements and stepped release pattern.)						
0.09	1.0	0	0.09	0.09	-0.56	0
0	-293	0	0	0	293	0
-4	0	-2	-2	2	0	
-60	-120	0	-60	-60	60	0
5	0	-26	5	5	-511	0
12	0	-56	12	12	-1,115	0
-4	-1	0	-4	-4	0	0
-120	-30	0	-120	-120	0	0
impact	No impact	No impact	No impact	No impact	No impact	No impact
y drought and the inability of the system to provide sufficient water (applies to all plans).						
impact	No impact	No impact	No impact	No impact	No impact	No impact
"	"	"	"	"	"	"
"	"	"	"	"	"	"
"	May lower value of some property near water.	"	"	"	"	"
"	Minor impact property tax because of above.		"	"	"	"
"	No impact	"	"	"	"	"
"	"	"	"	"	"	"
"	"	"	"	"	"	"
"	"	"	"	"	"	"
"	"	"	"	"	"	"

Item	1	2	3	4
Environmental impacts				
Manmade resources**	No impact	No impact	No impact	No imp
National resources**	"	"	"	"
Air quality**	"	"	"	"
C. Plan evaluation				
1. Contributions to planning objectives	Yes	Yes	Yes	Yes
2. Net beneficial and adverse effects (difference from Alt. 1)*				
a. NED				
(1) Beneficial ($1,000's equivalent annual 7-1/8% 10-year life)				
(a) Hydropower	-	60	-60	-120
(b) M&I water diversions ($30/AF) MWD	-	60	-120	-30
(c) Ending storage in Lake Mead ($30/AF)	-	-93	12	0
(2) Adverse ($1,000 equivalent annual 7-1/8%, 10-year life)				
(a) Salinity ($293,400/ppm)	-	0	0	-293
(b) Flood damages	-	13	19	-171
(c) Operation and maintenance		-7	-7	-12
(3) Net (beneficial minus adverse)	-	33	-156	-626
b. Environmental quality				
c. Regional development				(Insignificant
d. Social well being				(Insignificant

*All figures reflect average annual difference between given alternative and alternative 1
**Required by Section 122 of Public Law 91-611 (1970 Rivers and Harbors Act).

Table C-9 (Continued)

	Alternative					
	4	5	6	7	8	9
ct	No impact " "	No impact " "	No impact " "	No impact " "	No impact " "	No impact " "
	Yes	Yes	Yes	Yes	Yes	Yes
	-120	0	-60	-60	60	0
	-30	0	-120	-120	0	0
	0	-56	12	12	-1,115	0
	-293	0	0	0	293	0
	-171	-39	-15	8	39	14
	-12	-16	-14	-14	-17	-16
	-626	-111	-197	-174	-740	-2
	(Insignificant for all plans) (Insignificant difference among all plans)					

d alternative 1.
.

Table C-10. Number of structures subject to flooding in Parker Strip.

Type of structures	Number of structures	
	At 30,000 ft^3/s	At 40,000 ft^3/s
Residential.....	34	46
Mobile homes.....	17	90
Commercial.....	1	5
Semipublic.....	0	6
Total	52	147

Table C-11. Number of times in 100 years that floods would be equaled or exceeded through Parker Strip.

(Flows resulting solely from Hoover Dam releases.)

Flow	Alternative plan								
(ft^3/s)	1	2	3	4	5	6	7	8	9
30,000	4.0	4.0	4.0	0.90	4.0	4.0	4.0	0.8	4.0
40,000	0.32	0.30	0.60	0.71	0.59	0.49	0.56	Less than 0.1	0.58

Appendix D

EVALUATING THE THREAT OF OVERFLOWS INTO THE UNITED STATES

Appendix D

EVALUATING THE THREAT OF OVERFLOWS INTO THE UNITED STATES

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Appendix D

EVALUATING THE THREAT OF OVERFLOWS TO THE UNITED STATES

DESCRIPTION

1. This appendix evaluates the possibility of the Colorado River overflowing to the west in Mexico and flowing back into the United States. The information was compiled from a series of meetings among representatives of the U.S. and Mexico Sections of the International Boundary and Water Commission (IBWC), the Corps of Engineers, the Bureau of Reclamation, and Mexico's Ministry of Agriculture and Hydraulic Resources.

Background

2. The Colorado River delta region is about 4700 square miles, 55 percent of which is in Mexico. (See pl. D-1.) In prehistoric times, the Colorado River, from its fixed point near Yuma, gradually swung like a pendulum from a northerly course into the Salton Sink to a southerly course into the Gulf of California. Thus, the river distributed fertile soils, and formed the lands that now comprise the delta. The most dramatic recent change in the river course took place in 1905 when a series of floods from the Gila Basin enlarged the river and it adopted the just-completed Alamo Canal as its main channel. The entire river flowed in this new channel until 1907, discharging into the Salton Sink and forming what is known today as the Salton Sea.

3. The Imperial Irrigation District subsequently built numerous levees and channel dams to redirect the river course southward into the Gulf. Since construction of Hoover Dam in 1935, and other reservoirs later, Colorado River floods have been controlled, and the natural river channel changes have been minimized.

River Channel Changes

4. Major changes have occurred in the course of the Colorado River channel in the delta since 1900. Although some of these changes were influenced to some degree by manmade works, they were brought about primarily as a result of the natural delta-building processes of the river itself. Plate D-2 is a profile of the Colorado River Delta.

5. The Colorado River in its delta is a shallow meandering stream with low banks. It has never developed a channel that would contain the floodflows. Historically, overflows spread extensively over lands densely covered with vegetation, causing the water to rapidly drop its sediment, thus building up the lands along each course adopted by the river to form secondary deltaic cones.

6. Since 1905, the river has not developed a single continuous channel to the Gulf. Instead, it has divided into a multitude of small distributary channels that spread over extensive areas where much of the river sediment was deposited. This deposition caused relatively rapid raising of the riverbed upstream, which (together with overbank depositions) caused the river to become perched on the crest of a secondary cone of sands and silts along each of its courses.

7. Thus, it has been characteristic of the river (a) to develop overflow channels along the side slopes of each course, one of which was in time adopted by the river as its main channel, and (b) to repeat the natural cyclic process of delta building. This process accounts for the major changes in the river's course, as well as for the frequent minor changes that have marked the past history of the river in the delta. It also accounts for the difficulty in maintaining levees of sufficient height and strength to guard against overflow and against changes in the river's course. Extensive levee construction and repairs have been going on ever since 1905 in efforts to protect the lands and confine the river.

River Discharges

8. Stream gaging records, begun at Yuma in 1902, indicate that, before construction of Hoover Dam 322 miles above Yuma, the river's average annual discharge was about 15,100,000 acre-feet. Upstream records indicate that more than 90 percent of the discharge at Yuma came from above Hoover Dam. Before Hoover Dam was constructed, the river at Yuma had long-duration floods with peaks as high as 190,000 ft^3/s caused by late-spring snowmelt. The record flood at Yuma, 250,000 ft^3/s in January 1916, originated largely in the watershed of the tributary Gila River, which enters the Colorado River just above Yuma.

9. Since completion of Hoover Dam in 1935, flows at Yuma have been held to less than 35,000 ft^3/s. Floodflows in the Gila River watershed are controlled by Painted Rock Dam, built by the Corps of Engineers in 1959. Table D-1 shows the peak discharges of the Colorado River at Yuma since the record began in 1902. The marked reduction in annual peak discharge since 1935 caused by the collective regulating effect of all reservoirs in the Colorado River system is clearly evident. (See table 1 of main report.)

Table D-1. Colorado River Momentary Maximum Discharges.
(In ft^3/s)

Place	Year	Discharge	Place	Year	Discharge	
Yuma	1902	59,200		1941	30,400	
	03	73,000		42	31,800	
	04	51,500		43	19,000	
	05	112,000		44	21,200	
	06	109,000		45	22,900	
	07	116,000		46	16,800	
	08	62,700		47	14,200	
	09	150,000		48	21,300	
	1910	73,500		49	24,000	
	11	79,400		1950	22,900	
	12	146,000		51	16,100	
	13	63,600		52	23,600	
	14	141,000		53	24,300	
	15	102,000		54	18,200	
	16	250,000		55	18,100	
	17	144,000		56	3,970	
	18	94,900		57	3,390	
	19	58,100		58	15,800	
	1920	190,000		59	13,700	
	21	188,000		1960	10,300	
	22	117,000		61	8,900	
	23	101,000		62	2,170	Glen Canyon Dam
	24	69,800		63	5,050	completed
	25	53,200	Colorado	64	3,060	
	26	73,200	River at	65	8,040	
	27	92,400	Northerly	66	5,650	
	28	99,400	International	67	7,020	
	29	91,000	Boundary	68	4,910	
	1930	54,500		69	4,040	
	31	29,000		1970	6,560	
	32	90,800		71	3,430	
	33	70,700		72	5,290	
	34	22,900		73	3,930	
	35	15,600	Hoover Dam	74	3,590	
	36	9,520	completed	75	5,760	
	37	23,200		76	8,930	
	38	21,700		77	11,960	
	39	34,900		78	5,190	
	1940	13,800		79	9,680	
				80	13,800	

Notes: Discharge from IBWC Water Bulletins and U.S. Geological Survey Water Supply Papers: 1902-64, Colorado River at Yuma (record discontinued in 1964); 1965-79, Colorado River at Northerly International Boundary.

DISCUSSION

10. The following material discusses channel capacities and improvements, and well as a tidal sandbar.

Channel Capacities and Improvements

11. The topographic divide in the Colorado River Delta is about on a line between Yuma and Cerro Prieto Mountain. (See pl. D-1.) The natural drainage of lands north of this line runs into the United States; the natural drainage of those south of the line runs south into the Gulf. (See pl. D-2.)

12. The significance of this fact, in evaluating the threat of overflow to the United States, is that river overflows that might occur south of this line would not pose a threat to the United States. Conversely, the greatest threat to the United States could be created if river overflows were to occur north of this line. It was in this northern portion of the Mexicali Valley that levees were built, repaired, and rebuilt by predecessors to the Imperial Irrigation District between 1907 and 1937 to protect against overflows from the Colorado River in Mexico back into the United States.

13. The first line of levees on the west bank of the river (Ockerson levee) is still intact and has been strengthened and a paved road built along its crown. Most of the secondary levees built have been obliterated. But Mexico's leveed irrigation canals would serve as effective secondary barriers to any westward flows (pl. D-3).

14. The fact that there have been no Colorado River overflows from Mexico into the United States since 1907—even though extremely high floodflows have occurred, ranging from 150,000 ft^3/s to the maximum recorded flow of 250,000 ft^3/s in 1916 at Yuma (table D-1)—demonstrates the effectiveness of the levee and levee canal system from a flood control standpoint.

15. The Ockerson Levee forms the first line of defense. It is a 25-mile-long project that was first built in 1911, and later reconstructed and repaired numerous times. A 9-mile section of this levee extending from Southerly International Boundary northward stands today as the primary barrier against overflow of the Colorado River to the west. In the unlikely event that the river would break through the Ockerson Levee, Mexico's leveed canal and drain system stand as secondary lines of defense, guarding against possible overflow into the United States.

16. The Ockerson Levee is well constructed. Its top provides the base of a 2-lane paved highway; and in many areas, its slopes are heavily protected by rock. A November 1979 joint inspection by engineers from the U.S. Corps of Engineers, the Bureau of Reclamation, and the International Boundary and Water Commission (IBWC), U.S. Section, confirmed the structural integrity of the Ockerson Levee.

17. In October 1979, the Mexican Ministry of Agriculture and Hydraulic Resources furnished updated river profiles, cross sections, and other hydraulic data. Using these data, the IBWC, U.S. Section, evaluated levee heights in relation to expected flows. Mexico considered flows up to 28,000 ft^3/s. For purpose of analysis, the U.S. Section added to the Mexican profiles a preliminary water surface profile for a flow of about 70,000 ft^3/s.

18. The engineering analysis performed by the U.S. Section shows the following: From Morelos Dam south to San Luis, Mexico, the river is flanked on the United States side (east side) by the Yuma Levee, and on the Mexican side (west side) by the Ockerson Levee. Based on the Mexican water surface profiles (verified by the U.S. Section), the system in this reach can carry a flow of 28,000 ft^3/s with a levee freeboard of more than 3 feet on the United States side and more than 6 feet on the Mexican side. The U.S. Section's analysis using the Mexican profile shows the system in this reach can carry a flow of 70,000 ft^3/s with a levee freeboard of more than 4 feet on the Mexican side and more than 1 foot on the United States side.

19. From San Luis south to river kilometre 50 (31 miles below Morelos Dam), the system can contain a flow of 28,000 ft^3/s with a levee freeboard of more than 9 feet on the west side (Rodriquez Levee) and more than 3 feet on the east side (De Piedra Levee). (See pl. D-3.) A flow of 70,000 ft^3/s in this reach would encroach to within 6 feet of the top of the levee on the west side. On the east side up to river kilometre 48 (mile 30), there is at least 1.5 feet of freeboard above 70,000 ft^3/s.

20. Thus, it can be concluded that the levee system on the west bank of the Colorado River from the Northerly International Boundary to a point 35 river miles below Morelos Dam can contain a flow of 70,000 ft^3/s. The probability of a flow of this magnitude is very remote, less than once in a 1000 years; a flow of 28,000 ft^3/s can be expected about once in 140 years.

21. In the last 30 years, the high degree of reservoir control on the river has permitted few large flows to flush the river channel. As a result, sediment has built up and vegetation has encroached, reducing the main channel capacity. To offset this, however, overbank areas beyond the low flow channel, but within the levees, have been cleared for agricultural purposes, thereby removing obstructions to the passage of floodflows. The net effect probably is an increased capacity to carry large floodflows.

Tidal Sandbar

22. A tidal sandbar has developed in the main channel of the Colorado River near its mouth, where it empties into the Gulf of California. The sandbar is about 14 miles upstream from Montague Island, about 78 river miles south of the Southerly International Boundary (pl. D-1).

23. According to a 1979 river profile prepared by the Ministry of Agriculture and Hydraulic Resources of Mexico, the tidal sandbar is about 18 miles long, with about 5 miles of its top above the water surface. At its highest point, the sandbar is about 6 feet above the normal river channel bottom. Plate D-4 shows a profile of the tidal bar. The sandbar has been there at least since 1972, when its presence was noted on a satellite photo.

24. The tidal sandbar blocks the mouth of the river, restricting free flow of water into the Gulf. The sandbar has acted as a dam, raising stages in the Colorado River a few miles upstream. As a result, flooding has been aggravated along the lowermost reach of the river. The river, unable to follow its normal course, seeks paths to the Gulf on either side of the sandbar. Left to its own means, the river could, if high flows continue, reestablish a channel through the sandbar or claim as its main course one or both of the side routes. Mexico reports some flow through the sandbar but no evidence that the flow is cutting a new channel through the bar.

25. The tidal sandbar in no way can affect the movement of water northward to create a threat of overflow to United States. The main reason is that the elevations on the side of the sandbar range from sea level to 10 feet above sea level and that is significantly lower than the topographic divide to the north, which is about 35 feet above sea level. Also the leveed canals would block northward flow in any case.

26. It is understandable that Mexico has done nothing about removing the bar or cut a channel through it because the bar is so large and the initial and continuing cost of removing the sand would be enormous.

SUMMARY

27. In summary, there is virtually no possibility of Colorado River overflow to the west and into the United States because of the following factors:

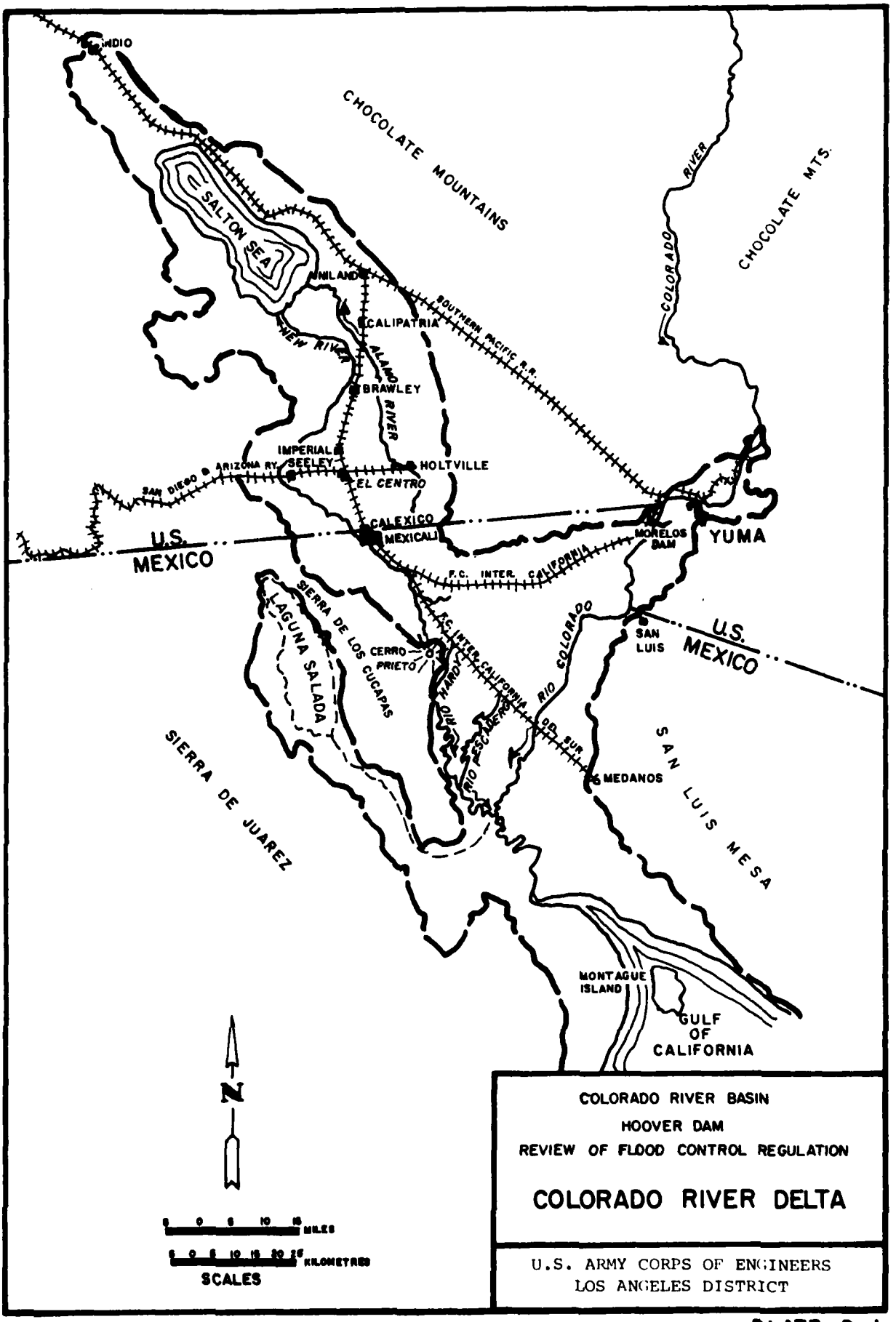
- The levees and leveed canals along the west bank of the Colorado River, which run about 35 miles below Morelos Dam, can safely contain a flow of 70,000 ft^3/s. A flow this size or larger is unlikely to occur.

- The Ockerson Levee, the primary line of defense agains overflow to the west and into the United States, is structurally sound. It probably is the strongest levee along the Colorado River in Mexico.

- The natural slope of the land and the leveed-canal and drain systems would direct overflows southward in the unlikely failure of Ockerson Levee.

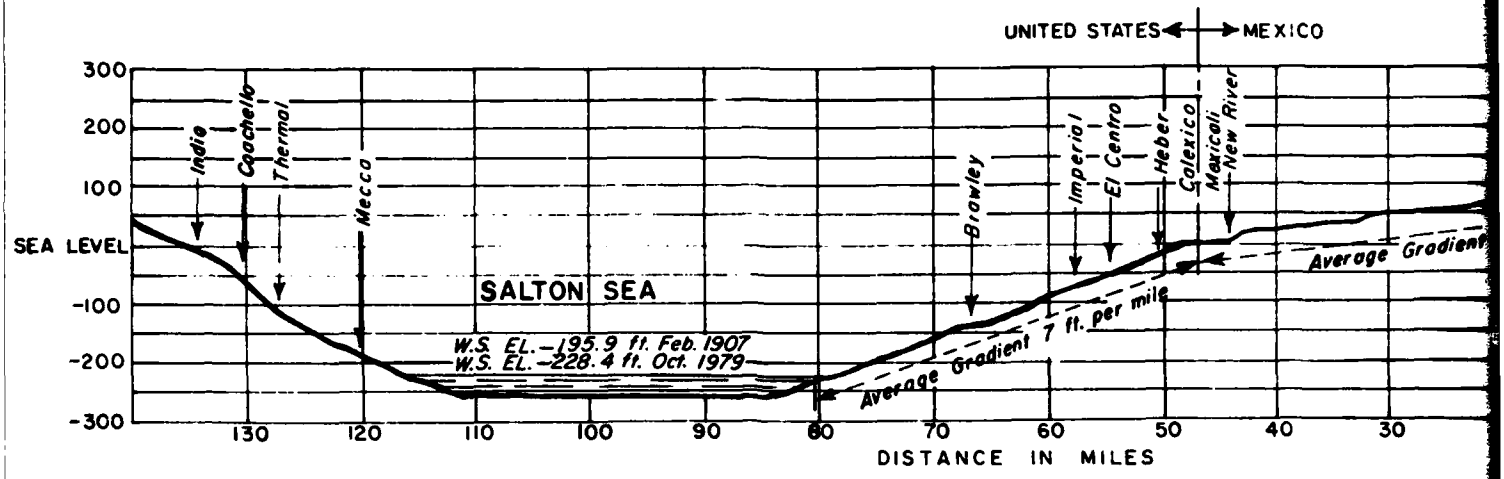
- Mexico is raising levees and making other improvements in the flood protection system along the Colorado River to protect valuable agricultural developments in the Mexicali Valley; and plans additional improvements.

- In the extremely unlikely failure of all the above protective measures that would make overflow to the west in the critical reach of the river imminent, Hoover Dam releases could be cut back allowing time for emergency repairs. Good quality rock is available in the nearby Andrade Quarry in the United States for emergency repairs.

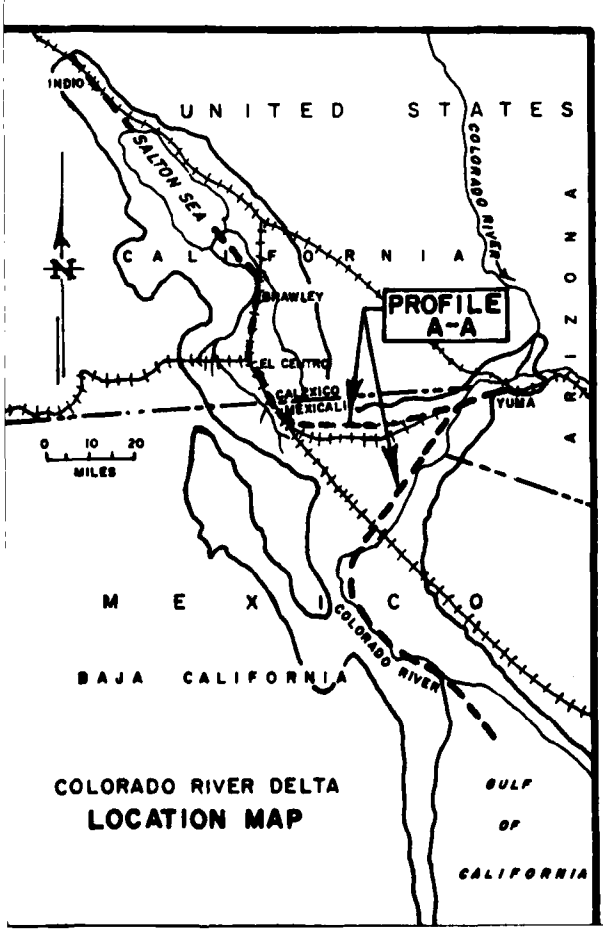


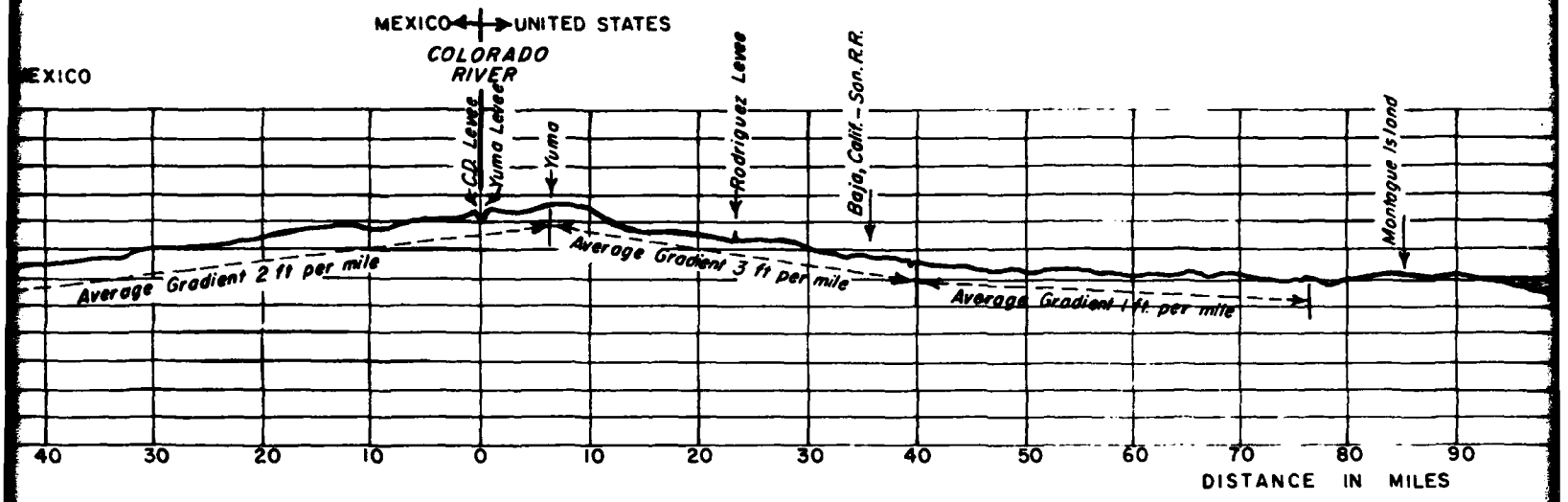
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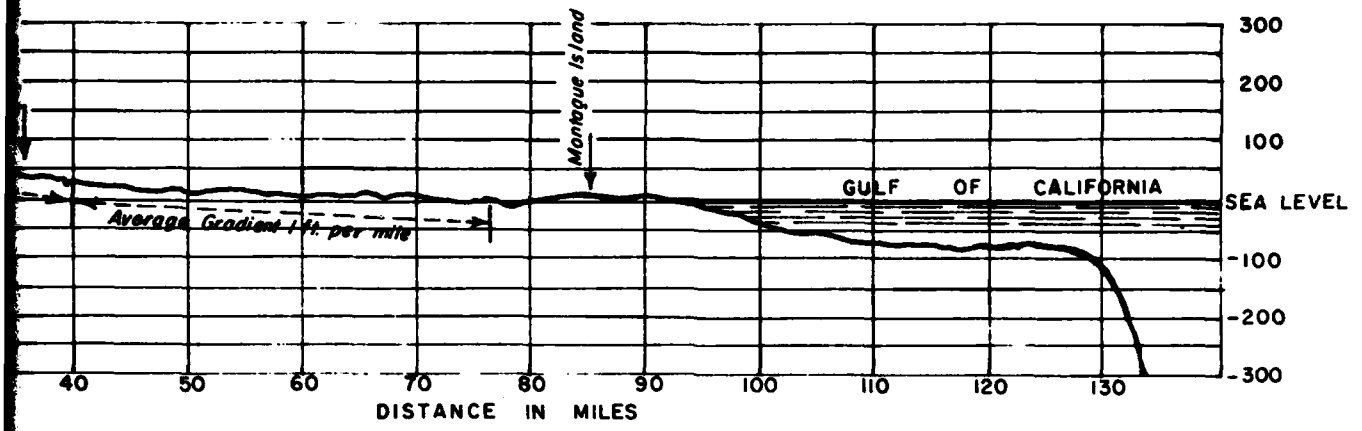
YUMA TO SALTON SEA





PROFILE A-A

YUMA TO GULF OF CALIFOR



YUMA TO GULF OF CALIFORNIA

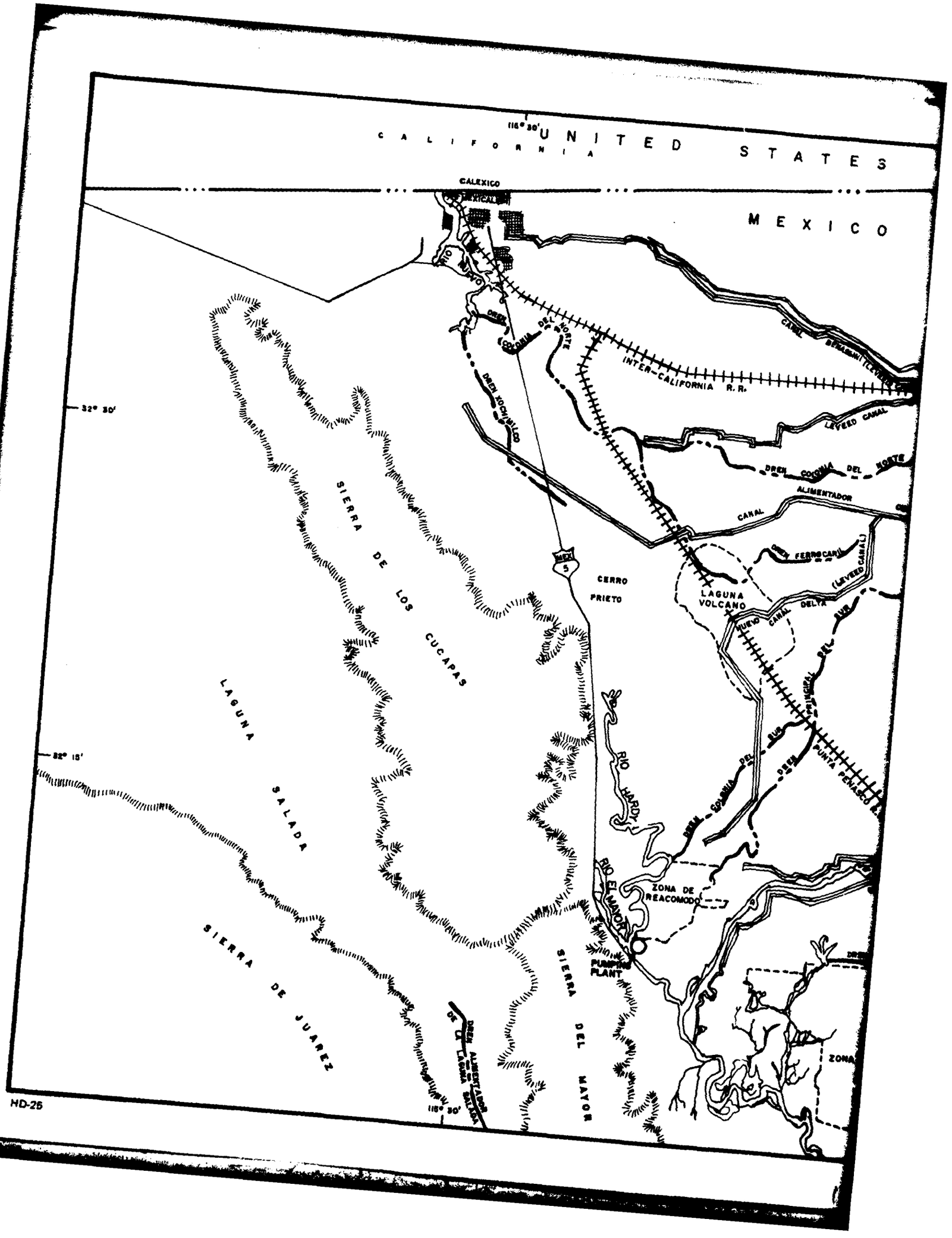
COLORADO RIVER BASIN

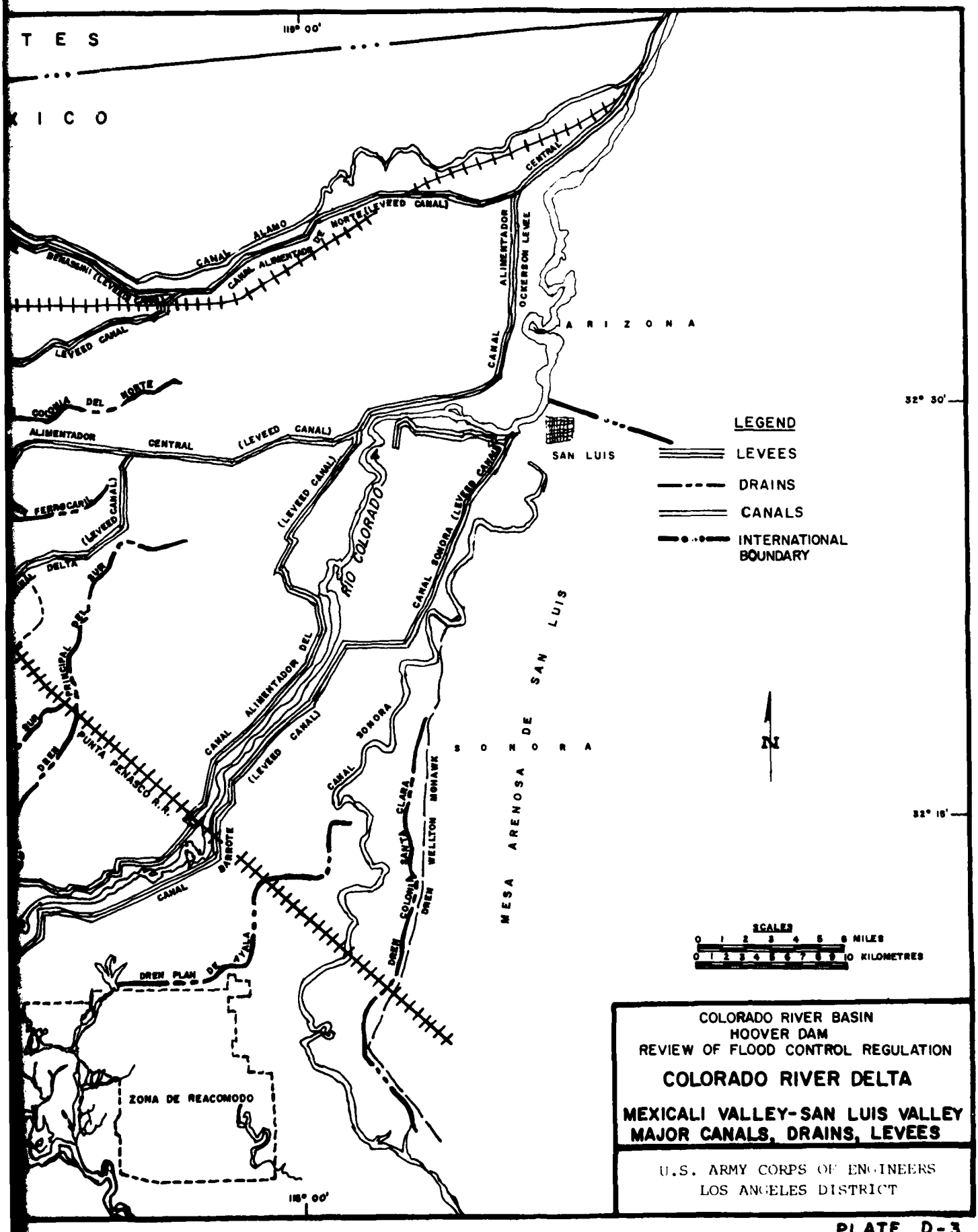
HOOVER DAM

REVIEW OF FLOOD CONTROL REGULATION

COLORADO RIVER DELTA PROFILE

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


CALIFORNIA
UNITED STATES
MEXICO
CALEXICO
116° 30'
32° 30'
32° 15'
RIO NUEVO
DREN COLONIA DEL NORTE
DREN XOCHIMILCO
INTER-CALIFORNIA R. R.
CANAL
LEVEED CANAL
ALIMENTADOR
DREN FERROCARRIL
(LEVEED CANAL)
MEX 5
CERRO PRIETO
LAGUNA VOLCANO
NUEVO CANAL
DELTA
RIO HARDY
DREN COLONIA DEL RIO
DREN PUNTA PEÑASCO
RIO EL MAYOR
ZONA DE REACOMODO
PUMPING PLANT
SIERRA DE LOS CUCAPAS
LAGUNA SALADA
SIERRA DE JUAREZ
SIERRA DEL MAYOR
DREN ALIMENTADOR LAGUNA SALADA
ZONA



COLORADO RIVER BASIN
HOOVER DAM
REVIEW OF FLOOD CONTROL REGULATION

COLORADO RIVER DELTA

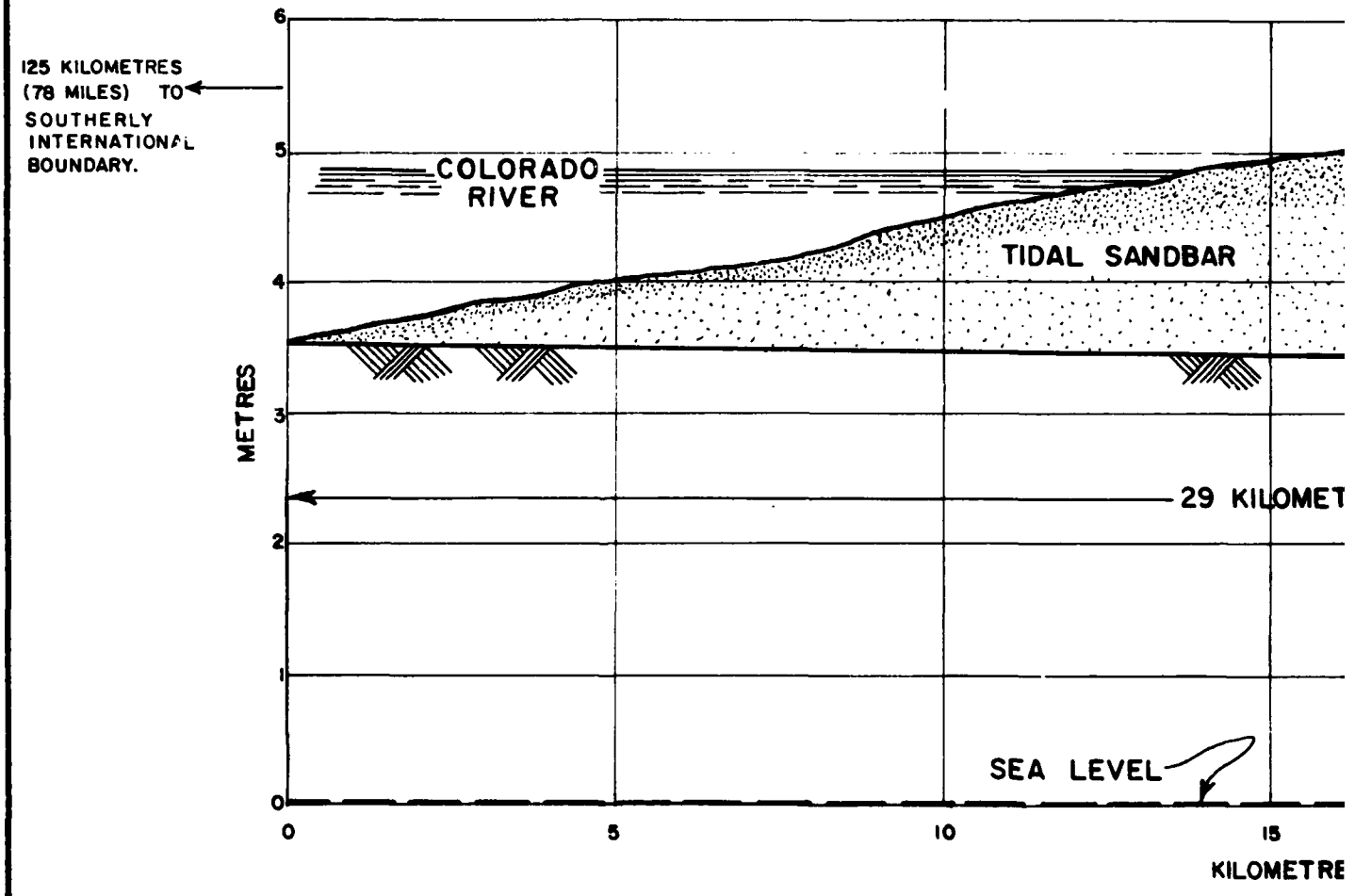
MEXICALI VALLEY-SAN LUIS VALLEY MAJOR CANALS, DRAINS, LEVEES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE D-3

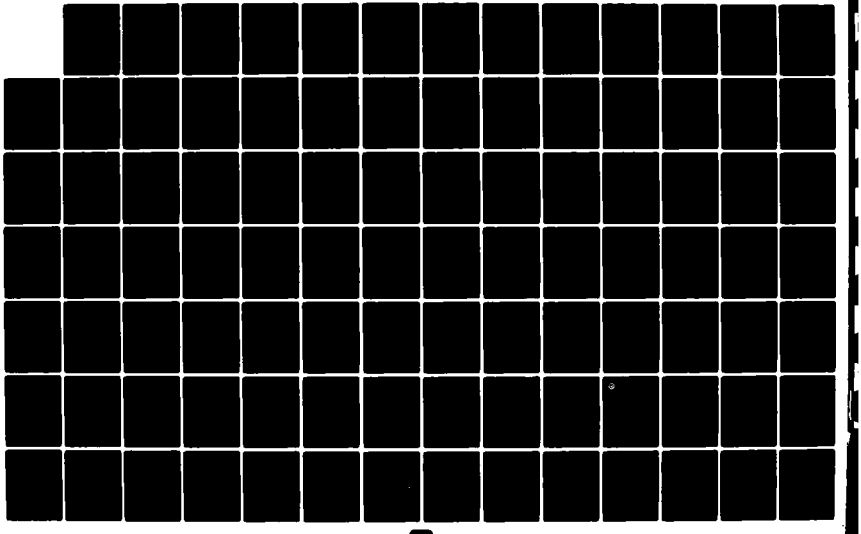
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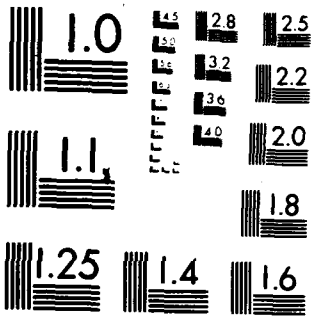
TIDAL SAND



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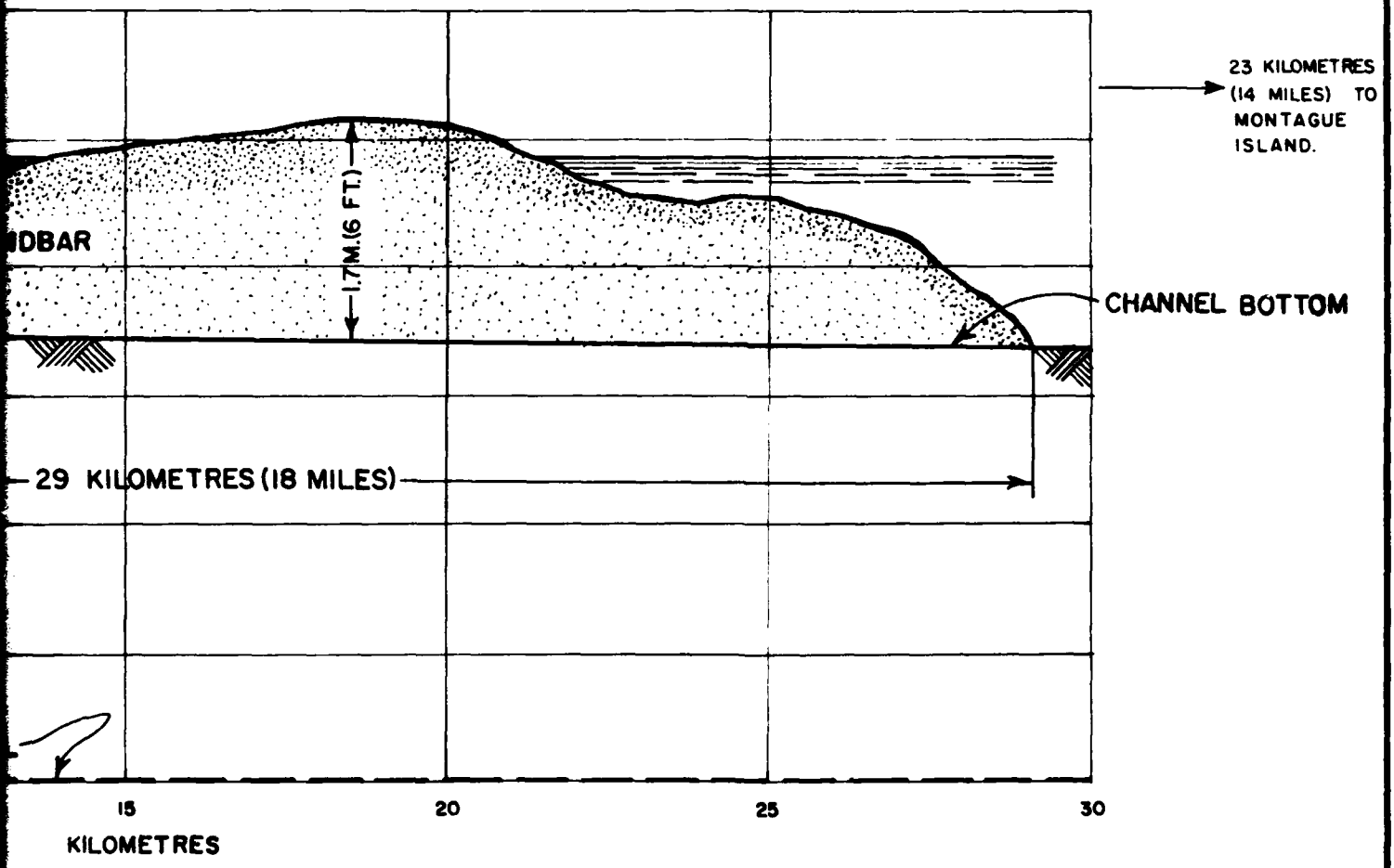




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

LORADO RIVER

IDAL SANDBAR



COLORADO RIVER BASIN

HOOVER DAM

REVIEW OF FLOOD CONTROL REGULATION

COLORADO RIVER

TIDAL SANDBAR

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

PLATE D-4

Appendix E
FINDING OF NO SIGNIFICANT IMPACT AND ENVIRONMENTAL ASSESSMENT

APPENDIX E

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United States Department of the Interior
Bureau of Reclamation
Lower Colorado Region, Boulder City, Nevada

Finding of No Significant Impact
Hoover Dam Flood Control Operating Criteria

FONSI NO. LC-82-7
Finding of No Significant Impact Number (Region)

Recommend: _____ 16 DEC 81
Regional Environmental Officer — Date

Approved: _____ MAR 11, 1982
Regional Director — Date

Finding of No Significant Impact
Hoover Dam Flood Control Operating Criteria

The Los Angeles District of the Corps of Engineers and the Lower Colorado Region of the Bureau of Reclamation have jointly conducted a water control study (entitled Colorado River Basin, Hoover Dam, Review of Flood Control Regulation, December 1981) culminating in a recommendation for a new flood control operation plan for Hoover Dam. The previous flood control operation plan established in 1968 was predicated on the condition that the non-damaging channel capacity below Hoover Dam was 40,000 ft^3/s. Investigations carried out as part of the water control study determined that the current non-damaging channel capacity is 28,000 ft^3/s. The recommended flood control plan seeks to maintain Hoover Dam releases at or below 28,000 ft^3/s to the extent practical to do so. The reduction in available non-damaging channel capacity resulted from the lack of high discharge flood control releases from Hoover Dam during the filling of Lake Powell from 1962 to 1980 in conjunction with developmental pressures along the river. Now that Lake Powell has filled, higher flows resulting from Hoover Dam flood control releases could be necessary. A return to a flow regime below Hoover Dam similar to the period prior to the construction of Lake Powell is anticipated.

In the water control study conducted by the Corps of Engineers and Bureau of Reclamation during 1977-1981, nine alternative flood control operation plans were formulated to test the significance of various flood control storage space allocations and patterns of flood control releases. Each of the plans was evaluated by considering its impact on flood control protection, water conservation, hydropower production, recreation, wildlife enhancement, water quality, and operation and maintenance costs. The 1968 flood control operation plan was not retained as an alternative because it was not a viable implementable operation plan. The 1968 plan called for releases of up to 40,000 ft^3/s, which would be damaging, during the preparatory space-building period (October through December) when no clearly demonstrable flood threat exists. However, alternative 1 in the water control study closely resembles the 1968 plan in that it retains the same January 1 and August 1 flood control storage allocation as the 1968 plan.

The environmental impacts of implementing any of the nine alternative flood control operation plans have been analyzed and described in the attached environmental assessment. A Finding of No Significant Impact (FONSI) is recommended for the proposed flood control operation plan based on the following reasons discussed in greater detail in the Environmental Assessment.

1. The recommended flood control operation plan is very similar to the 1968 plan and hence produces the same general environmental impact as the 1968 plan. Because the water regulating effect of the reservoir system on the Colorado River is so great, the operation of these reservoirs in effect establishes the riparian environment, which is significantly different from the natural (unregulated) riparian environment. The recommended plan is similar to the 1968 plan in three

basic ways: (a) the same flood control storage allocations are retained, (b) the flood control releases are based on forecasted inflow, (c) a release in excess of 40,000 ft^3/s is not made unless absolutely necessary.

2. The most significant changes called for the recommended plan, namely the extended space building period (August through December) and the stepped release pattern, tend to reduce the magnitude of maximum flood control releases as compared with the 1968 plan. The lower magnitude of required flood control releases and the more gradual shift from normal releases to flood control releases would result in less severe water level fluctuations, but longer inundation of shoreline areas. Although the lower flood control discharges of the recommended plan result in longer duration flows to achieve the same overall level of flood protection, the environmental impacts are less detrimental than higher flows.

3. Both positive and negative impacts will occur to terrestrial and aquatic resources under the proposed plan. These impacts will occur under all alternatives, including the no action plan, but are viewed as temporary and not significant because of the low probability of occurrence and short duration of the flooding expected. The impacts which can be expected include increased quality of backwater habitats in riverine areas, increased turbidity and scouring in mainstream habitats, and inundation of vegetation and therefore wildlife habitat during temporary flooding. Less severe water level fluctuations under the proposed plan will lessen impacts on established riparian communities. Impacts to aquatic habitat in reservoirs because of decreased water levels occur under the existing conditions and should not differ under the proposed plan.

4. The recommended plan would not adversely impact on any endangered species.

5. An archaeological analysis of the recommended plan revealed that no cultural resources proposed or eligible for inclusion on the National Register of Historic Places would be affected by the plan. A copy of this FONSI and the environmental assessment will be sent to the State Historic Preservation Officers of Arizona, California, and Nevada.

6. The recommended plan would not significantly affect the socioeconomic conditions of the region, except to provide a somewhat increased margin of protection to development in the flood plain.

After assessing the impacts associated with the recommended flood control operation plan, it is concluded that a FONSI meets the criteria established in the National Environmental Policy Act and an Environmental Impact Statement (EIS) is not required.

United States Department of the Interior
Bureau of Reclamation

Environmental Assessment
Hoover Dam Flood Control Operating Criteria

Lower Colorado Region
Boulder City, Nevada

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1. Introduction

1.1 Purpose

The Bureau of Reclamation (Bureau) and the Corps of Engineers (The Corps) are evaluating nine alternative Hoover Dam flood control operating criteria. The purpose of this environmental assessment is to determine if there are significant differences between alternative operating criteria in impacts on vegetation, fish, wildlife, or archaeological resources which could be used in the selection of the preferred flood control operating criteria.

1.2 Need

Since the closure of Glen Canyon Dam in 1962, storage space in Colorado River reservoirs has been in excess of that required to control floods. Today, storage in Colorado River reservoirs is near capacity and there is a high probability, over the next 10 years, that flood control releases from Hoover Dam will be required.

The current flood control operating criteria of Hoover Dam are predicated on a non-damaging downstream channel capacity of 40,000 ft^3/s. Analysis of the flood channel below Hoover Dam by the Corps indicated a 40,000 ft^3/s flow would be damaging today. The damages result primarily from development within the flood plain at Needles, along the Parker strip, and at Yuma.

Because of the above factors the reevaluation of Hoover Dam flood control operating criteria is important at this time. The major evaluating criteria used by the Corps are flood damages (primarily based on damages to structures in the flood plain), water conservation, and hydropower production. This assessment analyzes the effect of alternative flood control operating criteria on the natural environment.

2. Description of Alternatives

2.1 Nonviable Alternative

2.1.1 No Action

The selection of the no action alternative would mean continued operation of Hoover Dam under the existing flood control operating criteria. These operating criteria allow releases of up to 40,000 ft^3/s beginning October 1 to reach the required January 1 flood control space in Lake Mead and other upper basin reservoirs. Releases of 40,000 ft^3/s will cause economic damage downstream. Thus, the no action alternative is not a viable alternative because it could result in releases that cause economic damage when no demonstrable flood threat exists.

2.1.2 Restriction of Springtime Releases

An alternative discussed involved limiting sustained releases from Hoover Dam in the spring period to 20,000 ft^3/s. This kind of alternative is an effort to control floods while restricting releases from Hoover Dam to a level that results in lower Colorado River flows, essentially the same as have occurred over the last 20 years. This is not a viable alternative because restricting releases to this degree in the spring provides no flood protection and greatly increases the risk of extremely large flows.

2.2 Viable Alternatives

Nine alternative operating criteria were developed for evaluation (Table 1). Alternative number one is very similar to the existing operating criteria except releases are scheduled to begin on August 1 instead of October 1. This allows the requirements for January 1 flood control space in Lake Mead to be met without exceeding the 28,000 ft^3/s nondamaging downstream channel capacity.

Other alternatives were developed by varying the required January 1 flood control space and the stepped release schedule. Detailed descriptions of how all nine alternatives were formulated is located in the main report under the section entitled "Formulation of Alternative Plans."

3. Description of the Existing Environment

3.1 General

A 337-mile reach of the lower Colorado River will be affected by the flood control operating criteria of Hoover Dam. (See map 423-300-1455 in main report.) The area lies within the Southwestern climate zone (Green and Sellers 1964), typified by midwinter and midsummer rains. Drought predominates in other seasons. Local rainfall rarely exceeds 4 inches per year. Summer temperatures often are greater than 110^0 F, and winter temperatures seldom drop below freezing. Terrain ranges from precipitous cliffs, where the river passes through or by mountain ranges, to low broad flood plains. An account of the area's history, geology, soils, and hydrology may be found in the Department of the Interior's water quality reports (U.S. Department of the Interior, 1975 and 1977). Extensive bibliographies covering the lower Colorado River are also available (Yates and Marshall, 1974; USDA-SCA 1976; Desert Research Institute, 1976).

3.2 Aquatic Habitat

Three major aquatic habitats are currently present along the lower Colorado River: large reservoirs, flowing river channels, and small backwaters.

Table 1
Alternative Plans

	1 January (1) (MAF)	Maximum Controlled Release	Release Steps (1000 ft^3/s)
1	5.35	73,000	19, 28, 35, 40, 73
2	5.67	73,000	19, 28, 35, 40, 73
3	4.50	73,000	19, 28, 35, 45, 73
4	5.35	28,000	19, 28
5	5.35	35,000	19, 28, 35
6	4.50	40,000	19, 28, 35, 40
7	4.50	50,000	19, 28, 35, 40, 50
8	7.50	73,000	19, 28, 35, 40, 73
9	5.35	73,000	19, 28, 35, 50, 73

(1) All alternatives require 1.5 MAF Storage Space on August 1. Space building operations begin on August 1 for all alternatives.

Lake Mohave formed by Davis Dam, and Lake Havasu, formed by Parker Dam, are the major reservoirs south of Hoover Dam (Map No. 423-300-1455). The upper 20 miles of Lake Mohave remain a flowing environment. The remaining 47 miles of the lake are deeper and wider forming a lake environment. Small impoundments are formed by Headgate Rock and Imperial Dams.

Where not inundated by reservoirs, the river channel remains a flowing habitat. Unmodified reaches of the river channel range from 150 to 1,200 feet in width and up to 25 feet in depth. Most channelized or riprapped sections of the river are about 500 feet in width and 8 feet in depth.

Flows in the riverine reaches are determined by downstream water requirements and have not varied significantly since 1962. Average monthly flows vary seasonally and are highest in the spring and lowest in the winter (Figure 1). Reduced flows downstream result from diversions. Most of the water in the Colorado River is diverted upon reaching Imperial Dam. Flows in the channel below Imperial Dam result from irrigation return flows and ground water seepage. All water remaining in the river is diverted at Morelos Dam.

Daily fluctuations in water levels of 2 to 16 feet occur in riverine reaches below Hoover, Davis, and Parker Dams as water is released for daily power requirements. The magnitude of water level fluctuations lessens with distance downstream from the dams.

Many small backwaters occur along the river from Davis Dam to the Southerly International Boundary (SIB). Major backwater areas occur along the river within the Havasu National Wildlife Refuge, the Colorado River Indian Reservation, the Cibola National Wildlife Refuge, and the Imperial National Wildlife Refuge. Two additional backwaters, Gadsden Lake and Hunters Hole, are located along the river south of Yuma, Arizona.

Detailed descriptions of the limnology and aquatic flora and fauna occurring in these habitats can be found in studies by Minckley (1973 and 1976), Bryant (1976), Ponder (1975), Marshall (1976), Broadway and Herrgesell (1978), Priscu (1978), and the Arizona Cooperative Fishery and Research Unit (1975 and 1976). A list of fish species present in the Lower Colorado River System is shown in Table 2.

3.3 Terrestrial Habitat

The lower Colorado River flows through the lower Sonoran Life Zone. Vegetation surrounding Lake Mohave is characteristic of the Mohave Desert Scrub Community. Vegetation in this desert community is dominated by creosote bush (*Larrea tridentata*) and burro bush (*Ambrosia dumosa*). The formation of Lake Mohave eliminated the riparian zone on this reach of the river. However, small patches of riparian vegetation have developed along the shoreline of the lake. Salt cedar (*Tamarix pentandra*) is the dominant plant in the shoreline vegetation.

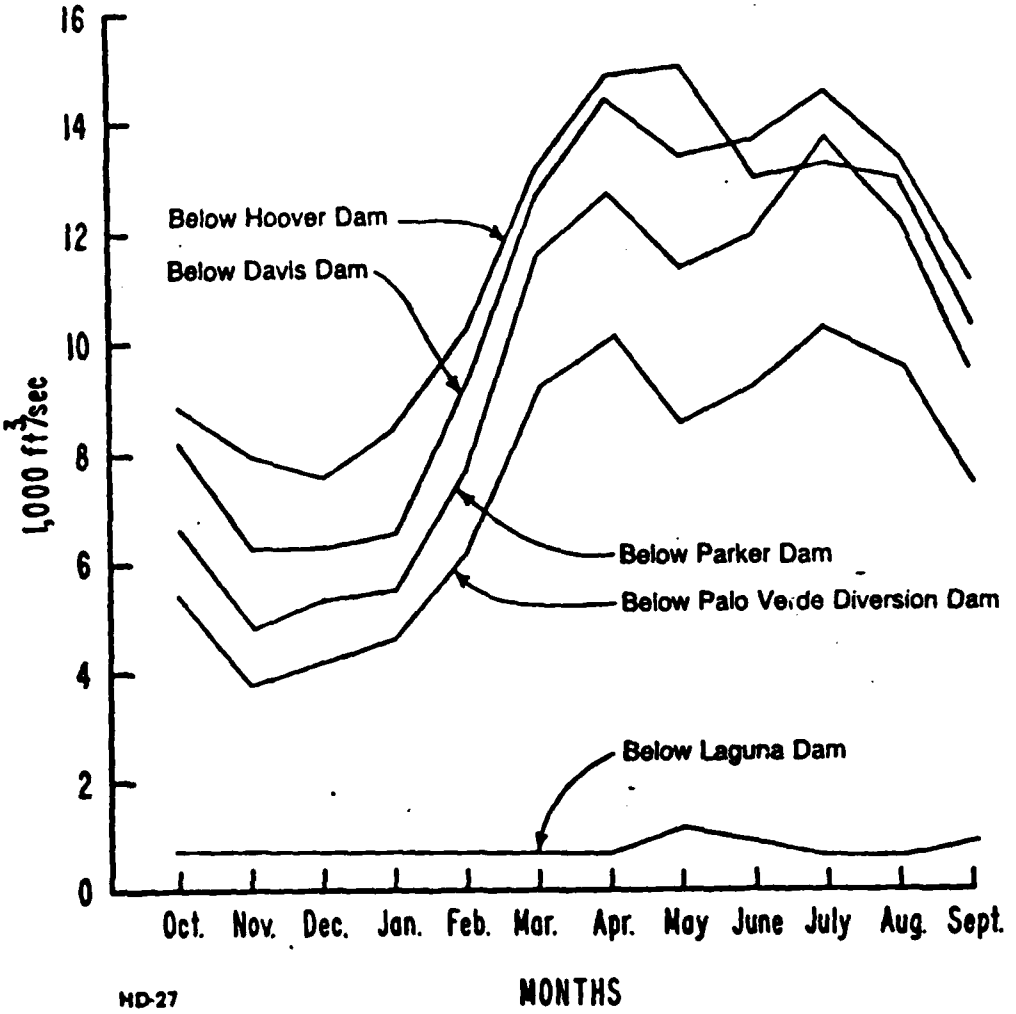


Figure 1. Average Monthly Flows Along the Lower Colorado River from 1967-1976.

Table 2

Major Fish Species in the Lower Colorado River From Hoover Dam to the Southerly International Boundary

Family	Species	
Catostomidae	Razorback sucker	Xyrauchen texanus
	Flannelmouth sucker	Catostomus latipinnis
Centrarchidae	Warmouth	Lepomis gulosus
	Green sunfish	Lepomis cyanellus
	Bluegill	Lepomis macrochirus
	Redear sunfish	Lepomis microlophus
	Largemouth bass	Micropterus salmoides
	Black crappie	Pomoxis migromaculatus
Cichlidea	Tilapia	Tilapia mossambica
	Zill's tilapia	Tilapia zilli
Clupeidae	Threadfin shad	Dorosoma petenense
Cyrinidae	Carp	Cyprinus carpio
	Golden shiner	Notemigonus crysoleucas
	Red shiner	Notropis lutrensis
	Goldfish	Carassius auratus
	Bonytailed chub	Gila elegans
	Fathead minnow	Pimephales promelas
Elopidae	Machete	Elops Affinis
Ictaluridae	Yellow bullhead	Ictalarus natalis
	Channel catfish	Ictalarus punctatus
	Black bullhead	Ictalarus melas
	Flathead catfish	Pylodictis olivaris
Malilidae	Striped mullet	Mugil cephalus
Percichthyidae	Striped bass	Morone saxatilis
Pocilidae	Mosquito fish	Cambusia affinus
	Sailfin mollie	Poecilia latipinna
	Mexican mollie	Poecilia mexicana
Salmonidae	Rainbow trout	Salmo gairdneri

The major terrestrial habitats that could be affected by changes in the flood control operating criteria of Hoover Dam occur between Davis Dam and the Southerly International Boundary (SIB). A total of 99,624 acres of riparian plant communities remain along this reach of the river (Table 3). These riparian communities have been divided into seven plant community types (Table 4). All community types, except marsh communities,were further divided into six structural types based on foliage volume (Table 5). The extent of all riparian plant communities within the flood plain below Davis Dam is shown on map sheets 1-23.

Detailed descriptions of the wildlife occuring along the lower Colorado River can be found in studies by Douglas (1977), Bradley and Deacon (1967), Anderson and Ohmart (1974, 1975, and 1976), and Vitt and Ohmart (1978). The species composition and seasonal densities of avian and small mammal populations occurring in riparian plant communities below Davis Dam is listed in the "Wildlife Use and Densities Report of Birds and Small Mammals in The Lower Colorado River Valley" (Anderson and Ohmart, 1977). A listing of the more common large mammals occurring along the lower Colorado River is shown in Table 6.

3.4 Special Status Species

The endangered Yuma clapper rail (Rallus longirostris yumanensis) inhabits marsh communities (map sheets 1-23) from Davis Dam to the SIB. The birds are generally migratory, arriving in late April and departing in late September. Breeding and nesting occurs from May through June (Ohmart and Smith, 1973). The winter range of the species is generally south of the SIB toward the Gulf of California. However, some rails winter north of the SIB in Topock Marsh, Topock Gorge, the Bill Williams River Delta, and on the Imperial National Wildlife Refuge. (Yuma Clapper Rail Recovery Team, 1977.)

The endangered bald eagle (Haliaetus leucocephalus) occasionally occurs on the lower Colorado River. A pair of these birds established a nesting territory on the Havasu National Wildlife Refuge near Topock Marsh in 1973. Although breeding behavior and nesting activities have been observed, no nesting attempts by this pair have yet been successful.

The California least tern (Sterna albifrons browni), the American peregrine falcon (Falco peregrinus anatum), and the brown pelican (Pelecanus occidentalis), are endangered birds which accidentally or occasionally visit the lower Colorado River. None of these species have known breeding sites in the study area.

Table 3
Total Acres of Riparian Vegetation From Davis Dam to the Southerly International Boundary

Community	Structural Type I	II	III	IV	V	VI	Total
Willow and/or Cottonwood	387	94	470	4448	2446	541	8386
Screwbean Mesquite-Salt Cedar	---	276	1880	13896	4615	362	21029
Honey Mesquite	---	---	1836	10553	4009	---	16398
Salt Cedar-Honey Mesquite	---	---	---	5985	2055	---	8040
Salt Cedar	107	191	338	25389	6948	2909	35879
Arrowweed	---	---	---	---	---	3989	3989
Marsh	---	---	---	---	---	---	5903
							99624

Table 4

Vegetative Communities and Criteria Used in Classification

Community	Criteria
Willow and/or Cottonwood	Populus fremontii and/or Salix gooddingii constituting at least 20% of the total trees
Screwbean Mesquite-Salt Cedar	Prosopis pubescens constituting at least 20% of the total trees
Honey Mesquite-Salt Cedar	Approximately equal numbers of P. velutina and Tamarix chinensis
Salt Cedar	T. chinensis constituting 95-100% of total trees
Honey Mesquite	P. velutina constituting 95-100% trees
Arrowweed	Tessaria sericea constituting 95-100% of total vegetation in area
Marsh	Emergent aquatic vegetation, primarily Typha sp.

Table 5

Structural Types and Criteria Used

Structural Type	Criteria
I	Three definite layers of vegetation with the majority of the vegetative volume at 20 feet or more.
II	Primarily one vegetative layer 20 feet or more.
III	No understory, with the canopy layer from 15-20 feet.
IV	A definite understory with the volume of the canopy from 10 to 15 feet.
V	A sparse area with the majority of the vegetative column at 5 feet and canopy trees not higher than 10 feet.
VI	One layer of vegetation with the bulk of the volume between 0-5 feet.

Table 6

Large Mammals Occurring Along the Lower Colorado River From Hoover Dam to the Southerly International Boundary

Common Name	Scientific Name
Coyote	Canis latrans
Gray Fox	Urocyon cinereoargenteus
Kit Fox	Vulpes velox
Mountain Lion	Felis concolor
Bobcat	Felis rufus
Badger	Taxiden taxis
Raccoon	Procyon lotor
Striped Skunk	Mephitis mephitis
Desert Cottontail	Sylvilagus auduboni
Black-tailed Jackrabbit	Lepus californicus
Beaver	Castor canadensis
Muskrat	Ondatra zibethica
Mule Deer	Odocoileus lemionus
Bighorn Sheep	Ovis canadensis
Feral Burro	Equus asinus

The bonytail chub (Gila elegans) has been officially listed as an endangered species by the Fish and Wildlife Service (FWS) as of April 24, 1980. This species may be extirpated from the lower Colorado River except for a few remaining adults in Lake Mohave and Lake Havasu (Minckley, 1973).

On May 27, 1980 the FWS withdrew its April 24, 1978 proposal to list the razorback sucker (Xyrauchen texanus) as a threatened species. Large numbers of this species remain in Lake Mohave (Bryant, 1976). The status of populations below Lake Mohave is unknown as few records have been recorded since 1962 (Minckley, 1973 and 1976). However, recent sampling efforts by California Department of Fish and Game indicate a substantial population of this species occurs in Senator Wash Reservoir (personal communication, Bill Loudermilk, California Department of Fish and Game).

3.5 Archaeological Resources

The lower Colorado River has not been extensively surveyed for cultural resources. The major studies are by Albert Schroeder (1951); Brooks, Alexander and Crabtree (1969/70); and Malcolm Rogers (1939, 1945). Schroeder carried out an extensive survey of the area from Davis Dam to the SIB. He gives a clear account of what is known of the movements and boundaries of the historic tribes of the lower Colorado area dating from 1540 A.D.

Schroeder described three different types of prehistoric sites on the lower Colorado River: farm campsites, permanent farm sites, and trail campsites. The farm campsites were seasonally occupied areas on sand dunes above or adjacent to the river's flood plain and were often located close to mesquite (Prosopis juliflora) and/or screwbean (Prosopis pubescens) groves. These sites were not termed permanent sites due to the small amount of material recovered, implying a short occupation period. Also these sites were situated on sand dunes that would have been isolated periodically during floods, therefore inhibiting year-round occupation.

The permanent farm sites are situated on the edge of the flood plain out of a normal flood danger. These sites were termed permanent because of their more extensive land area and materials recovered (Schroeder, 1951).

The trail campsites differ from the two previously mentioned sites in that they do not occur on sand dunes. They are situated away from the river in canyons, or in mountainous areas not suitable for farming. They also differ from the other sites in the small quantities of material recovered. The trail sites might well have been overnight stops or seasonal plan gathering camps (Schroeder, 1951).

The paucity of sites located in the flood plain along the lower Colorado River is most likely due to the tremendous floods the river caused prior to the building of the dams. Any cultural sites or evidence of aboriginal occupation not destroyed or buried by alluvial silt probably has been obliterated by the heavy equipment which leveled the land along the river for agricultural uses.

4. General Effects of High Flows on Fish and Wildlife Resources

Higher flows along the lower Colorado River will have positive and negative effects on terrestrial and aquatic environments. The nature of the effects will depend on the capacity of the river channel and the magnitude and duration of flow.

4.1 Vegetation

Five factors are important in determining the effect of changing water levels on plant communities (Teskey and Hinckley, 1977).

1) Time of year - Flooding during the growing season reduces growth rate of plants and can result in death to species with low tolerance to flooding. In areas subject to drought, flooding during the dormant season (fall-winter) increases soil moisture during the growing season. This additional soil moisture is beneficial to plant growth.

2) Flood Duration - Trees flooded for 1 month or less in the beginning of the growing season are often damaged and show the following symptoms: leaf chlorosis, leaf wilt, premature leaf drop, and diversed ratio. The amount of damage is related to the flood tolerance of the species. If the trees are not killed before the flood waters receed, recovery is usually rapid. Long term flooding (6 months or more) results in higher mortality. Most bottomland tree species cannot survive 2 years of continuous flooding.

3) Water depth - Water depth is most critical for seedlings and herbaceous species since water often covers them. If seedlings have not leafed out before flooding, they will often remain dormant until flood water receeds. If seedlings are not killed by the flood, they can leaf out again after floodwater receeds.

4) Sediment deposition plays an important role in plant survival. Floodwaters deposit clay, silt, and sand in low-lying areas. This can kill plants and reduce growth rates. Sediment deposition can also be beneficial by increasing long term productivity of the soil.

The impacts of flooding on plant communities also depends on the tolerances of individual species to flood damage. Three of the major tree species along the Colorado River (cottonwood, willow, and salt cedar) are very tolerant to damage by inundation (Teskey and Hinckley, 1977; Warren and Turner, 1975). The flood tolerance of screwbean and honey mesquite trees is not known.

4.2 Wildlife

All species of wildlife are initially displaced by rising water levels. Short term flooding (less than one month) can significantly reduce some small mammal populations (Blair, 1939; Blem and Blem, 1975; McCarley, 1959; and Stickel, 1948). Arboreal species are less susceptible to impact than those species that are strictly ground dwelling.

Large mammals capable of avoiding rising water levels are impacted less than small mammals. Bird populations are probably least affected by short term flooding, although some ground and marsh nesting species (e.g., Gambel's quail and Yuma clapper rail) could be affected.

Generally, the longer an area is inundated the greater the impact on terrestrial wildlife. After water levels receed, wildlife populations have the capacity to recover. Time required would vary with the species.

Flooding in the spring when many species are breeding is potentially more detrimental than flooding during other seasons of the year. Young are more suseptible to floodwaters and loss of large numbers of young (or reproductive attempts) could have a greater effect on populations. Disruption of breeding by the Yuma clapper rail would be of particular concern on the lower Colorado River.

Long term losses of wildlife populations as a result of flooding will not occur unless the duration of inundation results in the death of plant communities. In the event of habitat loss, recovery of wildlife populations would be related to the rate of succession of riparian plant communities. This is a very slow process and the time required would be measured in years.

4.3 Fish

Floods are a normal part of all stream ecosystems. Even though aquatic fauna have adapted to flowing water, high flows on the lower Colorado River will have both positive and negative effects (Grizzell, 1976). Potential benefits of higher flows are:

1) Existing flows in the Colorado River are so low at times during the year (figure 1) that water quality (low dissolved

oxygen, high temperatures, high salinities), especially in backwaters, is below that required for good fish production. Flows below Laguna Dam are very low year-round. Higher sustained flows in the river would raise water levels and improve the quality of fisheries habitat.

2) Daily fluctuations in water levels in riverine reaches below major dams is detrimental to productivity and reproduction. Sustained releases over that required for power would reduce daily water level fluctuations.

3) Many backwaters isolated from the river provide poor fisheries habitat because of low water quality and encroachment of vegetation. Higher flows could scour and freshen such backwaters improving the quality of fisheries habitat.

Potential negative effects of higher flows are:

1) At sustained higher flows, water velocity increases and the capacity of water to carry sediment deposits increases. Sediment deposition can directly affect fisheries by covering the bottom with a blanket of materials that kills bottom fauna, reduces food availability, and covers nests and spawning grounds.

2) If sustained flows are high enough, the capacity of the river to scour the bank and bottom is such that physical disruption of aquatic habitats occurs, e.g. changes in the course of the river channel or complete sediment deposition of backwaters.

3) Sustained higher flows in the spring when many species are spawning is potentially more detrimental than high flows during other seasons of the year.

5. Assessment of Higher Flows and Comparison of Alternatives

The magnitude of releases in the future will depend on the flood control operating criteria and the amount of spring runoff in the Colorado River Basin. The projected 1 month releases for each alternative operating criteria under different basin runoff conditions are shown in Tables 7, 10, 12, and 14. As a reference to gauge possible effects of higher flows on vegetation, map sheets 1-23 show the area inundated by 50,000 ft^3/s sustained flow and an approximate noninundating channel capacity (that sustained flow that can be carried in the existing channel without inundating a significant amount of terrestrial vegetation).

5.1 Hoover Dam to Davis Dam

5.1.1. Existing Channel and Flow Regime

Lake Mohave now forms this reach of the lower Colorado River. The river in the upper portion of the reach remains a flowing environment. Daily peak flows reach 35,000 ft^3/s in the summer. Minimum daily flows of 2,000 ft^3/s occur in the winter. Water levels fluctuate up to 16 feet daily in upper Lake Mohave.

Lower Lake Mohave is operated annually between 630 and 647 feet elevation at Davis Dam. Daily water releases from Hoover Dam do not significantly affect water levels in lower Lake Mohave.

5.1.2. Vegetation and Wildlife

The river channel in upper Lake Mohave is capable of carrying 40,000 ft^3/s. Projected sustained flows for all alternatives (Table 7) are less than the existing channel capacity. Projected 1 month sustained releases for flood events that could be expected to occur once every 100 years for all nine alternatives range from 28,000 - 35,000 ft^3/s. Releases within this range will cause no significant impacts to terrestrial vegetation or wildlife along this reach.

Lower Lake Mohave is currently operated between elevations 630 and 647 annually. No changes in the range of water levels is projected for excess water conditions for any of the alternative operating criteria. Thus, no impact to terrestrial vegetation or wildlife is expected along the shore of lower Lake Mohave with any flood control operating criteria.

5.1.3. Fish

Only two species of fish native to the Colorado River remain in the upper Lake Mohave, the razorback sucker and bonytail chub. Adult razorback suckers are present in substantial numbers (Bryant, 1976); however, it is not known if this species is reproducing under current conditions. Status of the bonytail chub is unknown. Excellent populations of rainbow trout are maintained by regular stocking of fish from Willow Beach National Fish Hatchery. No natural reproduction of this species is known to occur.

It is difficult to determine whether the change in the flows in upper Lake Mohave will have a net positive or negative effect on the fish present. The native species are adapted to high flow, turbid waters, and probably would be less affected than trout which are not adapted to high turbidity and high sediment loads. Examination of projected flow regimes (Table 7) indicates that the aquatic environment in upper Lake Mohave, under conditions requiring flood control releases would be essentially the same for all alternatives.

Table 7

Projected Sustained 1 Month Flows (in ft^3/s) in the Riverine Reaches from Hoover Dam to Lake Havasu for 9 Alternative Hoover Dam Flood Control Operating Criteria

Flood Frequency In Years 1/	Alternative Flood Control Operating Criteria									
	1	2	3	4	5	6	7	8	9	Range
100	35,000	35,000	35,000	29,000	35,000	35,000	35,000	28,000	35,000	28,000-35,000
50	35,000	35,000	35,000	28,600	35,000	35,000	35,000	28,000	35,000	28,000-35,000
20	29,500	29,500	29,500	28,300	28,800	29,200	29,200	28,000	29,200	28,000-29,500
10	28,000	28,000	28,000	28,000	28,300	28,000	28,000	28,000	28,300	28,000-29,500
5	27,100	27,100	27,000	28,000	28,000	27,000	27,300	28,000	28,000	27,000-28,000
2	18,700	17,800	17,800	18,700	17,700	18,000	17,700	19,000	18,500	17,700-19,000

1/ That flow that could be expected to occur an average of once in the designated number of years.

The aquatic environment of lower Lake Mohave will not be significantly altered by flood control releases projected during years of excess water in the basin. Existing releases cause underflowing along the bottom of the lake which is exited via the penstocks of Davis Dam. (Priscu, 1978). Flood control releases will follow this pattern and should not significantly change the existing limnological conditions of the lake.

5.2 Davis Dam - Lake Havasu

5.2.1. Existing Channel and Flow Regime

The channel from Davis Dam to Topock, Arizona has been dredged and riprapped. The remaining channel through Topock Gorge has not been dredged or riprapped. Daily summer peak flow rates below Davis Dam and at Topock, Arizona are 26,000 ft^3/s and 17,000 ft^3/s respectively. Summer minimum flows vary from 9,000-10,000 ft^3/s at both locations. Daily fluctuations in water level of up to 5 feet occur.

5.2.2. Vegetation and Wildlife

The river channel in this reach is capable of carrying sustained flows of approximately 28,000 ft^3/s (map sheets 1-5). Flows of this magnitude will begin to cause water levels to rise into surrounding vegetation. A sustained flow of 50,000 ft^3/s will raise water levels approximately 7 feet above normal at Topock, Arizona (map sheet 4) and inundate 5,655 acres of riparian vegetation along this reach (Table 8). The majority of vegetation inundated in this reach by a 50,000 ft^3/s flow results from the enlargement of the Topock Marsh backwater (map sheets 3 & 4).

Current operating criteria of Parker Dam require levels of Lake Havasu be reduced with increasing releases from Davis Dam (U.S. Bureau of Reclamation, 1977). This would decrease the area inundated by sustained high flows through Topock Gorge but increase the probability of scour in the lower end of the Gorge. With sustained flows greater than 20,000 ft^3/s, physical disruption of marshes in the lower portion of the Gorge could begin to occur.

Projected one month sustained flows for all alternatives for 2 through 20 year flood events along this reach are essentially the same (Table 7). Under 50 and 100-year flood events, alternatives 4 and 8 result in 29,000 ft^3/s and 28,000 ft^3/s releases. All other alternatives result in 35,000 ft^3/s releases. Sustained releases of 28,000 ft^3/s and 35,000 ft^3/s result in approximately 2½ and 3½ foot rises in water level above normal spring high water levels at Topock, Arizona (map sheet 4). Thus, the difference in water level rise at Topock, Arizona, between alternatives 4 and 8 and other alternatives could be approximately 12 inches.

Table 8

Number of Acres of Each Vegetation Type Inundated By 50,000 ft^3/s Sustained Flow From Davis Dam to Lake Havasu

Community Type	Structural Type I	II	III	IV	V	VI	Total
Willow and/or Cottonwood	---	---	---	553	---	---	553
Screwbean Mesquite-Salt Cedar	---	---	169	511	24	22	726
Honey Mesquite	---	---	161	185	25	---	371
Salt Cedar	---	---	---	25	---	---	25
Salt Cedar	49	---	187	913	75	728	1952
Arrowweed	---	---	---	---	---	80	80
Marsh	---	---	---	---	---	1948	1948
							5,655

Rises in water level of 2½ and 3½ feet will not overtop the retention dike at the south end of Topock Marsh. However, rises in water level within the marsh will occur as a result of high ground water levels and seepage through the dike. Differences in water level rise at the marsh between alternatives 4 and 8 and other alternatives for 50- and 100-year flood events would be less than 12 inches.

All alternatives result in releases along the reach, higher than have occurred in the recent past. The differences in magnitude of flows and rises in water between alternatives are not great enough to distinguish significant differences in impacts to vegetation and wildlife along this reach.

5.2.3 Fish

All alternative operating criteria will result in sustained releases higher than experienced in the past (Table 7). Sustained higher flows in the riverine reach from Davis Dam to Lake Havasu could improve aquatic habitats by reducing daily water level fluctuations. Rises in water levels and some increased scouring as a result of higher continued releases could benefit aquatic habitats in the backwaters of Topock Gorge by reducing sedimentation and vegetation encroachment and improving water quality.

Flows of 28,000 ft^3/s and above will begin to cause an enlargement of the backwater in Topock Marsh. An increase in water levels would improve water quality and be predominantly beneficial to aquatic habitats within Topock Marsh.

Under current operating criteria of Parker Dam water levels of Lake Havasu are lowered with increasing releases from Davis Dam. This generally would not affect aquatic habitats in the lake unless sustained releases reach 40,000 ft^3/s. At this magnitude of release lake levels must be lowered to the minimum elevation of 440 feet. This results in a six foot drop in the levels below normally experienced low water. Should this condition occur during the spring, spawning activities of largemouth bass could be disrupted.

Examination of projected flow regimes (Table 7) indicates that the changes in the aquatic environments from Davis Dam to Lake Havasu under excess water conditions would be essentially the same for all alternative flood control operating criteria.

5.3 Parker Dam to Palo Verde Dam

5.3.1 Existing Channel and Flow Regimes

The 14-mile reach of river channel from Parker Dam to Headgate Rock Dam has not been channelized (map sheets 8 and 10). The lower two-thirds of this portion of the reach is Lake Moovalya, the backwater of Headgate Rock Dam. Daily summertime flows range from a peak of 18,000 ft^3/s

to a minimum of 4,000 - 6,000 ft^3/s. Water levels fluctuate daily up to 6 feet below Parker Dam, up to 3 feet, 4 miles below the dam, and are reduced to 1 foot within Lake Moovalya, 7 miles below the dam. The low daily water level fluctuations over much of this reach have resulted in extensive recreational and residential development.

The river channel from Headgate Rock Dam to 1 mile below Agnes Wilson Road (map sheets 10 and 11) has been channelized. The remainder of the riverine reach to Palo Verde Dam is unaltered (map sheets 11-13). Daily summertime flows below Headgate Rock Dam range from a peak of 17,000 ft^3/s to a minimum of 3,000 ft^3/s. Daily summer time peak flows have attenuated to a peak of 13,000 ft^3/s with a minimum flow of 4,000 ft^3/s above Palo Verde Dam. Water levels fluctuate up to 5 feet daily below Headgate Rock Dam. These fluctuations have attenuated to several feet above Palo Verde Dam.

5.3.2 Vegetation and Wildlife

The river channel is capable of carrying sustained releases of approximately 28,000 ft^3/s and 20,000 ft^3/s without inundating a significant amount of terrestrial vegetation between Parker Dam and Headgate Rock Dam, and between Headgate Rock Dam and Palo Verde Dam (map sheets 8-13). Sustained flows up to channel capacity could benefit riparian plant communities by raising ground water levels.

A sustained 50,000 ft^3/s release could raise water levels aprproximately 7 feet and inundate 8,535 acres (Table 9) of riparian vegetation from Parker Dam to Palo Verde Dam. Sustained flows of 30,000 ft^3/s would raise water levels approximately 3 feet above normal high water levels between Parker and Headgate Rock Dams. The extensive development and almost total lack of any riparian vegetation in this portion of the reach (map sheets 8 and 10) minimize the potential for impacts to riparian vegetation and wildlife of releases above 28,000 ft^3/s.

Thirty thousand ft^3/s sustained releases will result in water level rises of approximately 4 feet above current high water levels between Headgate Rock Dam and Agnes Wilson Road (map sheets 10 and 11). Much of the channel at this portion of the reach is confined by high banks or levees. The major riparian plant community inundated by releases above 20,000 ft^3/s will be the Screwbean Mesquite - Salt Cedar community on Deer Island (map sheet 10).

The majority of the riparian plant communities inundated by 50,000 ft^3/s release along this reach occur between Agnes Wilson Road and Palo Verde Dam. Thirty thousand ft^3/s releases will result in water level rises of approximately 5 feet along this reach.

The potential for erosive damage by higher flows from Agnes Wilson Road to Palo Verde Dam is high. Bank erosion, realinement of the river channel, and some physical disruption of plant communities is possible with sustained flows above 20,000 ft^3/s.

Table 9

Number of Acres of Each Vegetation Type Inundated by a 50,000 $ft^{3/}s$ Sustained Flow From Parker Dam to Palo Verde Dam

Plant Community Plant	Vegetational Structure Type I	II	III	IV	V	VI		Total
Willow and/or Cottonwood	---	30	---	193	703	182		1108
Screwbean Mesquite-Salt Cedar	---	242	980	3349	285	133		4989
Honey Mesquite	---	---	---	265	126	---		391
Salt Cedar-Honey Mesquite	---	---	---	71	83	---		154
Salt Cedar	---	---	---	451	500	150		1101
Arrowweed	---	---	---	---	---	463		463
Marsh	---	---	---	---	---	---	329	329
								8535

Projected sustained flows for 2- through 100-year flood events along this reach are essentially the same for all alternatives (Table 10). All alternatives operating criteria result in releases along this reach higher than have occurred in the recent past. The differences in magnitude of flows and rises in water between alternatives are not great enough to distinguish significant differences in impacts to vegetation and wildlife along this reach.

5.3.3 Fish

All alternative operating criteria will result in sustained releases higher than experienced in the past for 5-year and greater flood events (Table 10). Sustained releases up to the channel capacity below Parker Dam could improve aquatic habitats by reducing daily water level fluctuations. With increasing releases up to and above channel capacity, Lake Moovalya will become more riverine than lakelike. Whether this would result in generally positive or negative impacts to aquatic fauna in the lake is problematic. However, at releases above 28,000 ft^3/s scouring of banks and movement of bottom sediment deposits could result in negative effects on the aquatic environment of Lake Moovalya.

Sustained releases up to the noninundating channel capacity (20,000 ft^3/s) between Headgate Rock Dam and Palo Verde Dam will have predominately positive effects on the riverine and backwater habitats. Such releases would reduce daily water fluctuation in the channel and improve water quality in backwaters. At higher sustained releases the potential for negative impacts to aquatic habitats increases. Releases above 20,000 ft^3/s could begin to physically disrupt banks and transport bottom sediment deposits.

Examination of projected flow regimes (Table 10) indicates that the change in the aquatic environment from Parker Dam to Palo Verde Dam, under excess water conditions, would be essentially the same for all alternatives.

5.4 Palo Verde Dam to Imperial Dam

5.4.1 Existing Channel and Flow Regimes

The river channel from Palo Verde Dam to Taylor Ferry (map sheets 13-16) has been improved and stabilized. Daily summertime flows range from a peak of 12,000 ft^3/s to a minimum of 5,000 ft^3/s. Daily water levels fluctuate up to 3 feet.

The river channel from Taylor Ferry to Adobe Ruins (map sheets 16 and 17) encompasses the Cibola cut and, except for the lower end, has been aligned and stabilized. Daily summertime peak and minimum flows are similar to those below Palo Verde Dam. Most of this portion of the reach is within the Cibola National Wildlife Refuge.

Table 10

Projected Sustained 1 Month Flows in the Riverine Reaches from Parker Dam to Palo Verde Dam for 9 Alternative Hoover Dam Flood Control Operating Criteria.

Exceedance Interval in Years 1/	Alternative Flood Control Operating Criteria									
	1	2	3	4	5	6	7	8	9	Range
100	32,100	32,300	32,300	28,000	32,100	32,300	32,300	28,000	32,000	28,000-32,300
50	32,000	32,000	32,000	28,000	32,000	32,000	32,100	28,000	32,000	28,000-32,000
20	28,000	26,900	26,800	27,800	28,000	26,800	26,800	26,400	28,000	26,400-28,000
10	26,300	26,000	25,500	26,100	26,300	25,700	25,700	26,000	26,300	25,500-26,300
5	24,400	24,400	24,300	24,400	24,300	24,500	24,300	24,800	24,000	24,000-24,800
2	15,700	15,500	15,000	15,300	15,300	15,700	15,300	15,700	15,300	15,000-15,700

1/ That flow that could be expected to occur an average of once in the designated number of years.

The river channel from Adobe Ruins to Imperial Dam has not been altered(map sheets 17-20). Summertime flows range from 9,000 to 12,000 ft^3/s. Daily fluctuations in water level has been reduced to less than 1 foot. Most of this portion of the reach is located within the Imperial National Wildlife Refuge.

5.4.2 Vegetation and Wildlife

The approximate noninundating channel capacities from Palo Verde Dam to Taylor Ferry, Taylor Ferry to Adobe Ruins, and Adobe Ruins to Imperial Dam are 20,000, 28,000, and 17,000 ft^3/s respectively (map sheets 13-20). Sustained flows up to 20,000 ft^3/s over the entire reach would be predominantly beneficial to riparian vegetation through augmentation of ground water.

A sustained 50,000 ft^3/s release will raise the water level 8-11 feet and inundate 14,514 acres of riparian vegetation from Palo Verde Dam to Imperial Dam (Table 11).

Sustained flows of 30,000 ft^3/s will also raise water levels 7 feet above current high water marks between Taylor Ferry and Adobe Ruins (map sheets 16 and 17). Because of the Cibola cut the river channel in this reach has high banks and is closely confined by levees. Releases above 28,000 ft^3/s will begin inundating vegetation and reach the levee, with depth of water rather than area inundated, being the major difference between flows up to 50,000 ft^3/s. Releases above 20,000 ft^3/s will begin to form a backwater on the west side of the river above Adobe Ruins (map sheet 17).

Sustained flows of 30,000 ft^3/s will cause rises in water level of 5 feet above current high water marks between Adobe Ruins and Imperial Dam. The potential for erosive damage in this portion of the reach is high. As flows increase above 20,000 ft^3/s, realinement of the river channel could occur. The possibility of avulsive channel movements is highest where the river bends sharply at Martinez Lake (map sheet 19).

Under existing flows, deposition of riverborne sediment at Imperial Dam has created problems in maintaining sufficient head for water deliveries to the Yuma Main Canal. Dredging above the upper face of the dam has been necessary to remove sediment. Higher flows will carry many times the sediment load of existing flows. At higher flows the potential for damage to plant communities, especially marshes, from sediment deposition exists in the lower portions of this reach (map sheets 19 and 20).

Table 11

Number of Acres of Each Vegetation Type Inundated By 50,000 ft^3/s Sustained Flow
Palo Verde Dam to Imperial Dam

Community Type	Structural Type I	II	III	IV	V	VI	Total
Willow and/or Cottonwood	---	18	337	1246	57	41	1699
Screwbean Mesquite-Salt Cedar	---	---	---	1649	216	181	2046
Honey Mesquite	---	---	---	28	---	---	28
Salt Cedar-Honey Mesquite	---	---	---	1569	5	---	1574
Salt Cedar	---	---	18	6242	776	91	7127
Arrowweed	---	---	---	---	---	47	47
Marsh	---	---	---	---	---	---	1993
							14,514

Projected one-month sustained flows for 2 through 100-year flood events along this reach are very similar for all alternatives (Table 12). All alternative operating criteria result in releases along this reach higher than have occurred in the recent past for flood events that could be expected to occur once in every 5 through once in every 100 years. The differences in magnitude of flows and rises in water level between alternatives are not great enough to distinguish significant differences in impacts to vegetation and wildlife along this reach.

5.4.3 Fish

Sustained releases up to 20,000 ft^3/s will have predominately positive effects on the riverine and backwater habitats from Palo Verde to Imperial Dam. Daily water level fluctuations would be reduced in the upper portions of the reach and water quality in the backwater improved. At higher sustained flows the potential for movement of bottom sediment deposits, sedimentation and physical disruption of aquatic habitats increases.

The potential for physical disruption of backwaters and riverine habitats is highest from Adobe Ruins to Imperial Dam (map sheets 17-20). Many of these backwaters are isolated from the river and are stagnating. Some scouring and increased exchange of water with the river would improve the aquatic habitat in the backwaters. However, excessive scouring or sediment deposition would be detrimental.

All alternative operating criteria will result in flows higher than experienced in the recent past for 5-year and greater flood events. Examination of the projected flow regime (Table 12) indicates that the change in the aquatic environment from Palo Verde Dam to Imperial Dam, under excess water conditions, would be essentially the same for all alternatives.

5.5 Imperial Dam to the Southerly International Boundary

5.5.1 Existing Channel and Flow Regimes

The river channel from Imperial Dam to the SIB (map sheets 20-23) has not been channelized. Flow in the river below Imperial Dam consists of return flows from the All-American Canal Desilting Works and small amounts of water used from occasional sluicing of sediment deposits into the Laguna settling basin. Return flow from irrigated areas reaches the river below Laguna Dam. The resulting year-round flow at Yuma, Arizona is approximately 500 ft^3/s. Flows of 4,000 ft^3/s, lasting several days, typically occur once a year when water released from Parker Dam exceeds available storage at Imperial Dam. All water in the river channel is diverted at Morelos Dam (map sheets 22 and 23).

Table 12

Projected Sustained 1 Month Flows in the Riverine Reaches from Palo Verde Dam to Imperial Dam for 9 Alternative Hoover Dam Flood Control Operating Criteria

Exceedance Interval in Years 1/	Alternative Flood Control Operating Criteria									
	1	2	3	4	5	6	7	8	9	Range
100	31,500	31,600	31,600	26,700	31,400	31,500	31,500	26,700	31,400	26,700-31,600
50	31,400	31,400	31,500	26,500	31,300	31,300	31,500	26,600	31,400	26,500-31,500
20	26,800	25,900	25,500	26,400	26,800	25,500	25,700	25,100	26,800	25,100-26,800
10	25,000	24,700	24,400	25,000	25,000	24,500	24,900	25,000	25,300	24,400-25,300
5	23,800	23,700	23,900	23,800	23,700	23,800	23,900	24,300	23,800	23,700-24,300
2	14,500	14,500	14,400	14,700	14,700	14,700	14,700	15,100	14,700	14,400-15,100

1/ That flow that could be expected to occur an average of once in the designated number of years.

5.5.2 Vegetation and Wildlife

Analysis of cross sections in this reach indicate the noninundating channel capacities from Imperial Dam to Laguna Dam and from Laguna Dam to the SIB are 17,000 and 5,000-9,000 ft^3/s, respectively.

Sustained flows up to the noninundating channel capacities will be predominantly beneficial to riparian plant communities and wildlife through augmentation of ground water.

A sustained release of 50,000 ft^3/s will inundate 8,330 acres of riparian vegetation along this entire reach (Table 13). A large proportion of the vegetation inundated by such a release is located between Imperial Dam and Laguna Dam (map sheet 20). There is very little elevational differential in the land surface in this area, thus flows above 17,000 ft^3/s will begin to inundate the entire area.

Sustained flows between 5,000-9,000 ft^3/s will begin inundating some areas of riparian vegetation between Laguna Dam and the SIB. Flows of 15,000 and 30,000 ft^3/s result in rises of 8 and 12 feet above normal water levels. Because of the extremely low past flow in this portion of the reach and the resulting encroachment of riparian vegetation adjacent to the river channel, flows approaching 15,000 ft^3/s will inundate all existing vegetation from Laguna Dam to SIB (map sheet 20-23). The potential for physical disruption of plant communities and impacts due to scouring is high with flows above 15,000 ft^3/s.

Projected one-month sustained flows (Table 14) are essentially the same for all alternatives for flood events that could be expected to occur once every 2 through once every 20 years. For 50- and 100-year flood event alternatives, 4 and 8 have lower projected flows (approximately 21,000 ft^3/s) than the other alternatives (approximately 28,000 ft^3/s).

Flows above 17,000 ft^3/s will begin inundating most of the plant communities between Imperial and Laguna Dams. Flows of 15,000 ft^3/s will raise water levels 8 feet and inundate all the vegetation from Laguna Dam to the SIB. Even with the difference in magnitude of projected flows at the 50- and 100-year flood events, all alternatives could result in flows that will inundate literally all the vegetation along this reach. Thus, no significant differences in impacts on vegetation and wildlife between alternatives are expected between Imperial Dam and the SIB.

Because of the small size of the river channel and proximity of vegetation, the probability of impacts to vegetation and wildlife under conditions of excess water is high under any of the alternative flood control criteria from Laguna Dam to the SIB.

Table 13

Number of Acres of Each Vegetation Type Inundated by 50,000 ft^3/s Sustained Flow From Imperial Dam to the Southerly International Boundary

Community Type	Structural Type I	II	III	IV	V	VI	Total
Willow and/or Cottonwood	---	---	8	437	337	---	782
Screwbean Mesquite-Salt Cedar	---	---	168	1214	24	---	1406
Honey Mequite	---	---	---	---	---	---	---
Salt Cedar-Honey Mesquite	---	---	---	---	---	---	---
Salt Cedar	---	---	---	4048	620	181	4849
Arrowweed	---	---	---	---	---	514	415
Marsh	---	---	---	---	---	878	878
							8,330

5.5.3 Fish

Sustained flows up to 5,000 to 9,000 ft^3/s could be predominantly beneficial to riverine and backwater fisheries habitat, particularly below Morelos Dam. The potential for detrimental effects to existing riverine habitats from Laguna Dam to SIB from physical disruption, increases for flows above 10,000 ft^3/s. Aquatic habitats of Hunters Hole and Gadsden Lake backwaters (map sheet 23) could be improved by some scouring and increased exchange of water with the river. However, excessive scouring or sediment deposition would be detrimental.

All alternative operating criteria will result in flows higher than experienced in the recent past for flood events that could be expected to occur once every 2 through once every 100 years. Examination of the projected flow regime (Table 14) indicates that the changes in the aquatic environments from Imperial Dam to the SIB under excess water conditions would be essentially the same for all alternatives.

5.6 Archaeological Resources

The extremely large floods that occurred along the lower Colorado River prior to the construction of any dams resulted in very few archaeological sites being located in the flood plain of the Colorado River. Because of the historic floods and depositional action of the river and the extensive use of agricultural equipment in the flood plain since dam construction, the flood plain area has a very low potential for any cultural resources.

Based on the above evidence we have concluded that the area inundated by a 50,000 ft^3/s sustained release (map sheets 1-23) does not encompass any properties that are on, or eligible for, inclusion on the National Register of Historic Places (Federal Register, Vol. 43, No. 26). All the alternative Hoover Dam flood control operating criteria have the capacity to control over 100-year flood events with releases substantially less than 50,000 ft^3/s. Thus, no significant differences in impacts to archaeological resources between alternatives can be determined.

6. Summary

The preceding comparison of existing noninundating channel capacities, current river flows, a 50,000 ft^3/s sustained flow, and projected river flows for alternative Hoover Dam flood control operating criteria under different runoff conditions in the Colorado River Basin provide an insight into how terrestrial and aquatic habitats along the lower Colorado River will be changed by higher flows. These comparisons also indicate that significant differences in environmental effects between alternatives cannot be shown based on the projected flows. Several points can be made:

Table 14

Projected Sustained 1 Month Flows in the Riverine Reaches from Imperial Dam to the Southerly International Boundary for 9 Alternative Hoover Dam Flood Control Operating Criteria

Exceedance Interval in years 1/	Alternative Flood Control Operating Criteria									
	1	2	3	4	5	6	7	8	9	Range
100	27,800	27,800	27,900	21,400	27,900	27,900	27,900	21,200	27,700	21,200-27,900
50	27,700	27,700	27,900	21,400	27,800	27,700	27,800	21,000	27,700	21,000-27,900
20	21,800	21,700	21,700	20,900	22,100	21,700	21,700	20,700	22,400	20,700-22,400
10	20,500	20,600	20,600	20,700	20,700	20,700	20,700	20,700	20,600	20,500-20,700
5	20,000	20,000	20,000	20,600	20,500	20,100	20,100	20,100	20,500	20,000-20,500
2	11,000	11,000	11,000	11,000	10,700	11,300	11,300	11,600	11,300	10,700-11,600

1/ That flow that could be expected to occur an average of once in the designated number of years.

1. Sustained releases up to 20,000 ft^3/s would be predominately beneficial to terrestrial and aquatic habitats from Davis Dam to Imperial Dam. As flows increase above 20,000 ft^3/s, potential for damage to terrestrial and aquatic habitat increases, especially through Topock Gorge, from Agnes Wilson Road to Palo Verde Dam, and from Adobe Ruins to Imperial Dam.

2. Below Imperial Dam sustained flows of 5,000-9,000 ft^3/s will be predominately beneficial to terrestrial and aquatic habitats. As flows increase above 10,000 ft^3/s the potential for damages to terrestrial and aquatic habitats increases along this reach. Because of the current channel conditions, the low past flow regime, and the proximity of vegetation to the river, the potential is high for some long term impact to terrestrial habitats below Imperial Dam.

7. Consultation and Coordination

Appendix G contains the mailing list for review of the draft review report which included this document, the comments received on the draft, and any responses to these comments.

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Appendix F
RECOMMENDED FIELD WORKING AGREEMENT

Appendix F

RECOMMENDED FIELD WORKING AGREEMENT BETWEEN DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION, AND DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS

Appendix F

RECOMMENDED FIELD WORKING AGREEMENT

Subsequent to the approval of this report by the South Pacific Division of the Corps of Engineers, a formal field working agreement between the Corps of Engineers and the Bureau of Reclamation will be consummated. The text of that agreement, which implements alternative 1 of this study, is presented in the remainder of this appendix.

FIELD WORKING AGREEMENT

BETWEEN

DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION

AND

DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS

FOR

FLOOD CONTROL OPERATION

OF

HOOVER DAM AND LAKE MEAD, COLORADO RIVER, NEVADA - ARIZONA

This field working agreement, made and entered into this _____ day of _____ 1982, between the Lower Colorado Region, Bureau of Reclamation and the South Pacific Division, Corps of Engineers,

WITNESSETH THAT:

WHEREAS, Hoover Dam and Lake Mead, Colorado River, Clark County, Nevada and Mohave County, Arizona, was authorized as part of the Boulder Canyon Project Act (Public Law 70-642). The Boulder Canyon Project Act states that Boulder Dam (Public Law 43 changed the name of the structure from Boulder Dam to Hoover Dam) and the reservoir that it creates shall be used: first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses; and third, for power.

WHEREAS, the Department of the Interior, acting through the Bureau of Reclamation, represented by the appropriate Regional Director, hereinafter referred to as the Regional Director, has constructed Hoover Dam and

Reservoir, and is responsible for the safety of the structure and for normal operations of the Lower Colorado River, of which said dam and reservoir are a part.

WHEREAS, the Department of the Army, acting through the Corps of Engineers, represented by its appropriate District and Division Engineers, is responsible for the flood control operation of Hoover Dam and Lake Mead in accordance with Section 7 of the 1944 Flood Control Act (Section 7, Public Law 78-534, 58 Stat. 890, 33 U.S.C. 709), which directs the Army to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds, and as promulgated in the Code of Federal Regulations, Title 33, Part 208.11, 13 October 1978.

WHEREAS, there is a need for a working agreement to insure a clear understanding of flood control regulations and information exchange required for the operation of Hoover Dam and Lake Mead.

NOW, THEREFORE, it is mutually understood and agreed by and between the parties hereto that this field working agreement shall consummate the provisions of the 1944 Flood Control Act for Hoover Dam and Lake Mead. In addition to the responsibilities of the project owner and the Corps of Engineers spelled out in paragraph 208.11, 33 CFR, it is agreed that Hoover Dam and Lake Mead will be operated in the interest of flood control in accordance with the following water control plan.

(a) In order to provide storage space for control of floods, releases from Lake Mead shall be scheduled so that available storage space for flood control will not be less than that indicated in the following table for the dates shown. Flood control storage space shall be the available storage space below elevation 1,229 feet.

Date	Available flood control storage space (acre-feet)
1 August	1,500,000
1 September	2,270,000
1 October	3,040,000
1 November	3,810,000
1 December	4,580,000
1 January	5,350,000

Pertinent information on permissible changes in available flood control storage space in Lake Mead is given in subparagraphs (1), (2), and (3) of this paragraph.

(1) The available flood control storage space in Lake Mead during the period 1 August to 1 January may be reduced to a minimum of 1,500,000 acre-feet, provided the additional space prescribed under paragraph (a) above is available in active storage space in upstream reservoirs. The maximum storage space in upstream reservoirs that can be credited to the 1 September, 1 October, 1 November, 1 December, or 1 January storage space requirement in Lake Mead is given in the following table:

Reservoir	Creditable storage space (Acre-feet)
Lake Powell	3,850,000
Navajo	1,035,900
Blue Mesa	748,500
Flaming Gorge plus Fontenelle	1,507,200

(2) Space building releases from Lake Mead during the period 1 August to 1 January shall not exceed 28,000 cubic feet per second. Space building releases are herein defined as releases for the purpose of attaining the available flood control storage space given in paragraph (a) above.

(3) If, however, available flood control storage space diminishes at any time to less than 1,500,000 acre-feet then the minimum flood control releases are described in paragraph (b) below.

(b) At any time during the year, if available storage space in Lake Mead should become less than 1,500,000 acre-feet, then minimum releases from Lake Mead for flood control shall be determined daily from table 1 (Minimum Flood Control releases from Hoover Dam throughout the year) using available flood control storage space in Lake Mead. Pertinent information on permissible changes in the releases as indicated in table 1 is given in subparagraphs (1), (2), and (3) of this paragraph.

(1) During 1 August to 1 January minimum releases from Lake Mead as given in table 1, if 40,000 cubic feet per second or less, shall not be reduced when once initiated until the storage space prescribed in paragraph (a) above becomes available. During the remainder of the year, releases as given in table 1 if 40,000 cubic feet per second or less are maintained until 1,500,000 acre-feet of storage is available at Lake Mead.

(2) Minimum releases from Lake Mead as given in table 1, if greater than 40,000 cubic feet per second, shall not be reduced, when once initiated, until Lake Mead water surface has receded to elevation 1,221.4 (top of spillway gates raised position). During 1 August to 1 January, releases may then be gradually reduced to 40,000 cubic feet per second and shall be maintained at not less than that rate until the storage space prescribed in paragraph (a) above becomes available. During the remainder of the year releases may also be reduced to 40,000 cubic feet per second upon reaching elevation 1,221.4 in Lake Mead, and shall be maintained at not less than that rate until 1,500,000 acre-feet of storage space is available at Lake Mead.

(3) The releases required in table 1 are minimum releases. Based on forecasted inflow, releases when the Lake Mead water surface elevation is between 1219.61 feet and 1229.00 may be higher during the early stages of a flood so as to achieve a greater reduction in ultimate peak outflow.

(c) Releases from Lake Mead shall be restricted to quantities that will not cause a flow in excess of 40,000 cubic feet per second at the gaging station, Colorado River below Davis Dam, insofar as possible.

However, with the reservoir water surface at the top of the flood control pool, a discharge of about 65,000 cubic feet per second will be passing over the Hoover Dam spillways with the gates in the raised position.

(d) For the period 1 January through 31 July, minimum releases from Lake Mead to attain the 1 August flood control space prescribed in paragraph (a) above shall be determined by use of the Flood Control Algorithm described in Exhibit 1 and Water Loss Equations for Lakes Mead and Powell described in Exhibit 2. Pertinent information on inflow forecasts and on permissible changes in the prescribed releases is given in subparagraphs (1), (2), (3), (4), (5), and (6) of this paragraph.

(1) All inflow forecasts used in carrying out the provisions of these regulations shall be prepared by the Colorado River Forecasting Service located in the National Weather Service River Forecast Center in Salt Lake City, Utah and shall be for the flow of the Colorado River into Lake Mead including the runoff contribution from the tributary drainage area between Lake Powell and Lake Mead.

(2) Lake Mead inflow forecasts as provided by the Colorado River Forecast Service shall be determined from depleted flow. Depletion of natural (virgin) flow shall include transbasin diversions, net water use (diversion minus return flow), and evaporation from reservoirs upstream of Lake Powell. Adjustments to the forecast provided by the Colorado River Forecast Service shall be made for effective storage space in upstream reservoirs as specified in subparagraph (3) of this paragraph. The

maximum forecast for any specified runoff period is defined as the estimated inflow volume (acre-feet) that, on the average, will not be exceeded 19 times out of 20.

(3) Effective storage space in Navajo, Blue Mesa, and Flaming Gorge plus Fontenelle reservoirs is the lesser of the actual space available, or the usable space available. The usable space is the difference between the mean forecasted inflow volume (acre-feet) for any specified runoff period and projected mean reservoir releases. In computing effective storage space for Flaming Gorge plus Fontenelle, the actual space is the sum of the actual available space in both reservoirs; while mean forecasted inflow volume and projected mean reservoir release will be the values at Flaming Gorge reservoir. Effective storage space in a reservoir(s) may be a negative value if projected mean reservoir releases exceed the mean forecasted inflow volume.

(4) When minimum releases for the months of January through July as determined by the Flood Control Algorithm are less than 28,000 cubic feet per second, it will be permissible to release less than the indicated amounts for a part of a month, provided the average releases for the entire month will equal the release given by the Algorithm, without flows exceeding 28,000 cubic feet per second at the gaging station, Colorado River below Davis Dam.

(5) The Flood Control Algorithm described in Exhibit 1 accounts for storage space in Lakes Powell and Mead. Whenever sufficient runoff occurs, Lake Powell is expected to fill to capacity (water surface

elevation 3700.0 feet) and Lake Mead is expected to fill to capacity (water surface elevation 1219.61), and remain full until 1 August so as to preclude any increase in the flood control releases specified by the Flood Control Algorithm above 28,000 cubic feet per second at the gaging station, Colorado River below Davis Dam.

(6) The objective of the Flood Control Algorithm is to specify releases such that Lake Mead will be no higher than water surface elevation 1219.61 feet (1,500,000 acre-feet of available storage space below elevation 1229.0 feet) on 1 August. Subsequent revisions to the minimum releases specified by the Flood Control Algorithm may be made during July if justified by a forecast of the remaining runoff and comparison with empty reservoir space available.

(e) During the period 1 January through 31 July the larger release specified by the Flood Control Algorithm versus table 1 shall be the required minimum release.

(f) At anytime of the year, Hoover Dam releases shall not result in a flow rate greater than 28,000 cubic feet per second at the gaging station, Colorado River below Davis Dam unless required or authorized by these regulations.

(g) Nothing in this agreement shall be construed to require dangerously rapid changes in magnitudes of releases. Releases will be made in a manner consistent with requirements for protecting the dam, reservoir and appurtenances from major damages.

(h) Hoover Dam is but one of three major flood control reservoirs in the Lower Colorado River Basin. The Corps of Engineers operates Alamo Dam on the Bill Williams River and Painted Rock Dam on the Gila River. In that flows on these tributary streams contribute to the mainstem Colorado River, coordinated operation of all three reservoirs is essential to achieving flood control objectives. Hence temporary deviations from the Hoover Dam releases prescribed in this regulation may be necessary after consideration of the available storage, projected inflows, and required releases from these tributary reservoirs.

(i) The Bureau of Reclamation shall procure such current basic hydrologic data, and make such current calculations of permissible releases from Lake Mead as are required to accomplish the flood control objectives prescribed above.

(j) The Bureau of Reclamation shall keep the Los Angeles District Engineer, Corps of Engineers, Department of the Army, in charge of the locality, currently advised of reservoir releases, reservoir storage, and such other operating data as the District Engineer may request, and also of those basic operating criteria that effect the schedule of operation.

(k) The flood control regulations are subject to temporary modification by the Los Angeles District Engineer, Corps of Engineers, if found necessary in time of emergency. Requests for and action on such modifications may be made by the fastest means of communications available. The action taken shall be confirmed in writing the same day to the office of the Regional Director and shall include justification for the action.

(l) The Regional Director may temporarily deviate from the flood control regulations in the event an immediate short-term departure is deemed necessary for emergency reasons to protect the safety of Hoover Dam and Lake Mead, or downstream dams, or the levee systems along the lower Colorado River. Such actions will be immediately reported by the fastest means of communication available. Actions shall be confirmed in writing the same day to the Los Angeles District Engineer, Corps of Engineers, and shall include justification for the action.

(m) The Bureau of Reclamation shall be responsible for providing adequate warnings to downstream interests when changes in release of stored floodwaters are made.

(n) Revisions to the flood control operation for Hoover Dam and Lake Mead may be developed as necessary by the parties of this agreement. Each such revision shall be effective on the date specified.

IN WITNESS WHEREOF, the parties hereto have caused this memorandum of agreement to be executed as of the day and date first above written.

Corps of Engineers

BY:_____
Brigadier General, USA
Division Engineer
South Pacific Division

Bureau of Reclamation

BY:_____
Regional Director
Lower Colorado Region

Table 1. Minimum flood control releases from Hoover Dam throughout the year.

CRITERIA	RELEASES
Water surface elevation between 1219.61 and 1221.40 feet (available storage between 1,500,000 and 1,218,000 acre-feet)	Make releases equal to inflow up to 28,000 cubic feet per second
Water surface elevation between 1221.40 and 1226.90 feet (available storage between 1,218,000 and 340,000 acre-feet)	Make outflow equal to inflow up to 40,000 cubic feet per second
Water surface elevation between 1226.90 feet to 1229.00 (available storage between 340,000 and 0 acre-feet	Make outflow equal to inflow up to 65,000 cubic feet per second
At water surface elevation 1229.00 (top of the flood control pool)	Maintain outflow equal to inflow

NOTE:

Water surface elevation (feet)	Water in storage (millions of acre-feet)	Available storage (millions of acre-feet)	Level
1205.40	23.708	3.669	Permanent spillway crest
1219.61	25.877	1.500	Minimum required flood control pool
1221.40	26.159	1.218	Top of spillway gates in raised position
1226.9	27.037	0.340	Spillway discharge equals 40,000 cubic feet per second with spillway gates in raised position
1229.00	27.377	0	Top of flood control pool
1232.00	---	0	Top of dam

EXHIBIT 1

FLOOD CONTROL ALGORITHM

The flood control algorithm is applicable during the period of 1 January through 31 July.

Definitions.

FI = the forecasted depleted inflow volume (in million acre-feet) to Lake Mead during the current month through 31 July, which will not be exceeded 19 times out of 20, and has been adjusted for effective storage space in selected upstream reservoirs excluding Lake Powell. FI is referred to as the maximum forecast.

SSM = current storage space (in million acre-feet) in Lake Mead below elevation 1229.0 feet.

SSP = current storage space (in million acre-feet) in Lake Powell below elevation 3700.0 feet.

RRM_N = the Hoover Dam hypothetical average release rate (in cubic feet per second at a specific step rate corresponding to the subscript N) through 31 July excluding the current month. Step values are as follows:

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Release Step	Release Rate (cubic feet per second)
RRM_0	0
RRM_1	19,000
RRM_2	28,000
RRM_3	35,000
RRM_4	40,000
RRM_5	73,000

RCM = the Hoover Dam average release rate (in cubic feet per second) during the current month determined from solution of the volumetric equation given below.

FCR = the Hoover Dam average release rate (in cubic feet per second) required for flood control during the current month.

NCM = the number of days in the current month.

NRM = the number of remaining days from the present through 31 July excluding the current month.

BSM = the Lake Mead water loss (in million acre-feet) to bank storage during the current month through 31 July.

EVM = the Lake Mead water loss (in million acre-feet) due to evaporation at the lake surface during the current month through 31 July.

BSP = the Lake Powell net water loss (in million acre-feet) due bank storage during the current month through 31 July.

EVP = the Lake Powell net water loss (in million acre-feet) due to evaporation and precipitation during the current month through 31 July.

Detailed procedure and equations used to define the terms BSM, EVM, BSP and EVP are presented in Exhibit 2.

The volumetric equation applied to determine RCM is as follows:

$$FI = SSM + SSP - 1.5 + 1.9835 \times 10^{-6}((RCM \times NCM) + (RRM_N \times NRM)) + BSM + EVM + BSP + EVP$$

Solution of equality of the volumetric equation is iterative using progressively increasing step values of RRM_0 through RRM_5. RRM_N must be the smallest step value satisfying the requirement that RCM must be equal to or less than RRM_N.

The required Hoover Dam flood control release FCR during the current month is determined according to either condition a or b as follows:

(a) if RCM is greater than or equal to RRM_{N-1} then, FCR = RCM

or

(b) if RCM is less than RRM_{N-1} then, FCR = RRM_{N-1}

EXHIBIT 2

WATER LOSS EQUATIONS FOR

LAKES MEAD AND POWELL

July 1982

LAKE MEAD

$BSM = 0.065 (SSM - 1.5)$

$EVM = (NEM) (AAM \times 10^{-6})$

where:

BSM = the Lake Mead water loss (in million acre-feet) to bank storage during the current month through 31 July.

SSM = current storage space (in million acre-feet) in Lake Mead below elevation 1229.0 feet.

EVM = the Lake Mead water loss (in million acre-feet) due to evaporation at the lake surface during the current month through 31 July.

AAM = the average reservoir surface area (in acres) on Lake Mead from the current month through 31 July.

NEM = the average evaporation depth (in feet) for Lake Mead from the current month through 31 July as follows:

Month	Evaporation Rate (feet)
January	0.36
February	0.33
March	0.37
April	0.46
May	0.53
June	0.64
July	0.80

LAKE POWELL

BSP = 0.15 (SSP)

BSP = the Lake Powell water loss (in million acre-feet) to bank storage during the current month through 31 July.

SSP = current storage space (in million acre-feet) in Lake Powell below elevation 3700.0 feet.

$$EVP = (C_1E^4 + C_2E^3 + C_3E^2 + C_4E + C_5)\ (SM)$$

where:

EVP = the Lake Powell net water loss (in million acre-feet) due to evaporation and precipitation during the current month through 31 July.

E = the average water surface elevation of Lake Powell (in feet above mean sea level) from the current month through 31 July.

SM = a coefficient for the current month through 31 July as follows:

Period	Coefficient
January - July	0.536
February - July	0.486
March - July	0.439
April - July	0.380
May - July	0.313
June - July	0.222
July	0.118

Constants are as follows:

$C_1 = -1.06524 \times 10^{-12}$

$C_2 = 1.68872 \times 10^{-8}$

$C_3 = -9.51439 \times 10^{-5}$

$C_4 = 0.229605$

$C_5 = -2.0211176 \times 10^{2}$

The equations in Exhibit 2 may be revised based on prudent engineering analysis without requiring formal revision of the total field working agreement. Revision would be effective following written agreement between the Regional Director and the Division Engineer. All revised versions of Exhibit 2 shall be labeled indicating the date of revision before being effective.

SIMPLIFIED APPLICATION OF THE FLOOD CONTROL REGULATION TO DETERMINE APPROXIMATE RELEASES

The following set of tables 1 through 7 provide approximate values of required January through July flood control releases from Hoover Dam for use as a convenient reference or guide. The simplifying assumption made in deriving these tables is that Lake Powell is full to elevation 3700 feet, and all available storage space for both Lakes Mead and Powell occurs at Lake Mead. Hence all bank storage changes and evaporation loss determinations for both Lake Powell and Lake Mead are assumed to be equivalent to the water losses and/or gains that would occur at Lake Mead only.

The true value of the required flood control release from Hoover Dam must be determined from use of the Flood Control Algorithm in exhibit 1 of the Field Working Agreement.

TABLE 1 - MINIMUM AVERAGE JANUARY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON JAN 1	MAXIMUM JANUARY-JULY FORECAST IN MILLION ACRE-FEET 1/																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
MILLION ACRE-FEET	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
2	0	0	0	0	19	19	28	33	37	40	40	40	40	40	40	72	73
3	0	0	0	0	12	19	24	28	35	40	40	40	40	40	40	54	73
4	0	0	0	0	0	19	19	28	31	35	40	40	40	40	40	40	70
5	0	0	0	0	0	10	19	22	28	35	40	40	40	40	40	40	52
6	0	0	0	0	0	0	19	19	28	29	35	40	40	40	40	40	40
7	0	0	0	0	0	0	8	19	21	28	35	40	40	40	40	40	40
8	0	0	0	0	0	0	0	19	19	28	28	35	40	40	40	40	40
9	0	0	0	0	0	0	0	6	19	19	28	35	40	40	40	40	40
10	0	0	0	0	0	0	0	0	19	19	28	28	35	40	40	40	40
11	0	0	0	0	0	0	0	0	5	19	19	28	35	40	40	40	40
12	0	0	0	0	0	0	0	0	0	19	19	28	28	35	40	40	40
13	0	0	0	0	0	0	0	0	0	3	19	19	28	35	40	40	40
14	0	0	0	0	0	0	0	0	0	0	18	19	28	28	35	40	40
15	0	0	0	0	0	0	0	0	0	0	1	19	19	28	35	40	40
16	0	0	0	0	0	0	0	0	0	0	0	16	19	28	28	35	40
17	0	0	0	0	0	0	0	0	0	0	0	0	19	19	28	35	39

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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TABLE 2 - MINIMUM AVERAGE FEBRUARY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON FEB 1	MAXIMUM FEBRUARY-JULY FORECAST IN MILLION ACRE-FEET 1/																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
MILLION ACRE-FEET	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
2	0	0	0	17	19	28	35	40	40	40	40	40	46	73	73	73	73
3	0	0	0	0	19	20	28	35	40	40	40	40	40	63	73	73	73
4	0	0	0	0	15	19	28	35	40	40	40	40	40	44	73	73	73
5	0	0	0	0	0	19	19	28	35	40	40	40	40	40	61	73	73
6	0	0	0	0	0	12	19	28	33	40	40	40	40	40	42	73	73
7	0	0	0	0	0	0	19	19	28	35	40	40	40	40	40	58	73
8	0	0	0	0	0	0	10	19	28	31	40	40	40	40	40	40	73
9	0	0	0	0	0	0	0	19	19	28	35	40	40	40	40	40	56
10	0	0	0	0	0	0	0	8	19	28	29	38	40	40	40	40	40
11	0	0	0	0	0	0	0	0	19	19	28	35	40	40	40	40	40
12	0	0	0	0	0	0	0	0	6	19	28	28	36	40	40	40	40
13	0	0	0	0	0	0	0	0	0	19	19	28	35	40	40	40	40
14	0	0	0	0	0	0	0	0	0	4	19	27	28	35	40	40	40
15	0	0	0	0	0	0	0	0	0	0	19	19	28	35	40	40	40
16	0	0	0	0	0	0	0	0	0	0	2	19	25	28	35	40	40
17	0	0	0	0	0	0	0	0	0	0	0	19	19	28	35	40	40

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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TABLE 3 - MINIMUM AVERAGE MARCH RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON MAR 1	MAXIMUM MARCH-JULY FORECAST IN MILLION ACRE-FEET 1/																
MILLION ACRE-FEET	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
2	0	0	3	19	28	35	40	40	40	40	51	73	73	73	73	73	73
3	0	0	0	18	19	28	35	40	40	40	40	66	73	73	73	73	73
4	0	0	0	1	19	28	35	40	40	40	40	49	73	73	73	73	73
5	0	0	0	0	16	19	28	35	40	40	40	40	64	73	73	73	73
6	0	0	0	0	0	19	28	34	40	40	40	40	47	73	73	73	73
7	0	0	0	0	0	14	19	28	35	40	40	40	40	62	73	73	73
8	0	0	0	0	0	0	19	27	32	40	40	40	40	45	73	73	73
9	0	0	0	0	0	0	13	19	28	35	40	40	40	40	60	73	73
10	0	0	0	0	0	0	0	19	25	30	40	40	40	40	43	73	73
11	0	0	0	0	0	0	0	11	19	28	35	40	40	40	40	58	73
12	0	0	0	0	0	0	0	0	19	23	28	40	40	40	40	41	73
13	0	0	0	0	0	0	0	0	9	19	28	35	40	40	40	40	56
14	0	0	0	0	0	0	0	0	0	19	21	28	39	40	40	40	40
15	0	0	0	0	0	0	0	0	0	7	19	28	35	40	40	40	40
16	0	0	0	0	0	0	0	0	0	0	19	19	28	37	40	40	40
17	0	0	0	0	0	0	0	0	0	0	5	19	28	35	40	40	40

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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TABLE 4 - MINIMUM AVERAGE APRIL RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON APR 1	MAXIMUM APRIL-JULY FORECAST IN MILLION ACRE-FEET 1/																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
MILLION ACRE-FEET	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
2	0	0	19	28	35	40	40	40	59	73	73	73	73	73	73	73	73
3	0	0	5	19	28	40	40	40	41	73	73	73	73	73	73	73	73
4	0	0	0	19	27	35	40	40	40	57	73	73	73	73	73	73	73
5	0	0	0	3	19	28	40	40	40	40	73	73	73	73	73	73	73
6	0	0	0	0	19	25	35	40	40	40	55	73	73	73	73	73	73
7	0	0	0	0	1	19	28	38	40	40	40	71	73	73	73	73	73
8	0	0	0	0	0	17	23	35	40	40	40	53	73	73	73	73	73
9	0	0	0	0	0	0	19	28	36	40	40	40	69	73	73	73	73
10	0	0	0	0	0	0	15	21	33	40	40	40	51	73	73	73	73
11	0	0	0	0	0	0	0	19	28	35	40	40	40	67	73	73	73
12	0	0	0	0	0	0	0	13	19	31	40	40	40	49	73	73	73
13	0	0	0	0	0	0	0	0	19	28	35	40	40	40	65	73	73
14	0	0	0	0	0	0	0	0	11	19	29	40	40	40	47	73	73
15	0	0	0	0	0	0	0	0	0	19	28	35	40	40	40	63	73
16	0	0	0	0	0	0	0	0	0	9	19	28	40	40	40	45	73
17	0	0	0	0	0	0	0	0	0	0	19	28	35	40	40	40	61

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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TABLE 5 - MINIMUM AVERAGE MAY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON MAY 1	MAXIMUM MAY-JULY FORECAST IN MILLION ACRE-FEET 1/																
MILLION ACRE-FEET	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
2	0	11	26	35	40	40	68	73	73	73	73	73	73	73	73	73	73
3	0	0	19	28	40	40	50	73	73	73	73	73	73	73	73	73	73
4	0	0	9	24	35	40	40	66	73	73	73	73	73	73	73	73	73
5	0	0	0	19	28	40	40	48	73	73	73	73	73	73	73	73	73
6	0	0	0	7	22	35	40	40	64	73	73	73	73	73	73	73	73
7	0	0	0	0	19	28	40	40	46	73	73	73	73	73	73	73	73
8	0	0	0	0	5	20	35	40	40	62	73	73	73	73	73	73	73
9	0	0	0	0	0	19	28	40	40	44	73	73	73	73	73	73	73
10	0	0	0	0	0	3	19	35	40	40	60	73	73	73	73	73	73
11	0	0	0	0	0	0	19	28	40	40	43	73	73	73	73	73	73
12	0	0	0	0	0	0	1	19	35	40	40	58	73	73	73	73	73
13	0	0	0	0	0	0	0	17	28	40	40	41	73	73	73	73	73
14	0	0	0	0	0	0	0	0	19	33	40	40	56	73	73	73	73
15	0	0	0	0	0	0	0	0	15	28	38	40	40	71	73	73	73
16	0	0	0	0	0	0	0	0	0	19	31	40	40	54	73	73	73
17	0	0	0	0	0	0	0	0	0	13	28	36	40	40	69	73	73

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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TABLE 6 - MINIMUM AVERAGE JUNE RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON JUN 1	MAXIMUM JUNE-JULY FORECAST IN MILLION ACRE-FEET 1/																
MILLION ACRE-FEET	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
2	0	24	40	44	73	73	73	73	73	73	73	73	73	73	73	73	73
3	0	15	32	40	60	73	73	73	73	73	73	73	73	73	73	73	73
4	0	0	22	40	42	73	73	73	73	73	73	73	73	73	73	73	73
5	0	0	13	30	40	58	73	73	73	73	73	73	73	73	73	73	73
6	0	0	0	19	40	40	73	73	73	73	73	73	73	73	73	73	73
7	0	0	0	11	28	40	56	73	73	73	73	73	73	73	73	73	73
8	0	0	0	0	19	39	40	72	73	73	73	73	73	73	73	73	73
9	0	0	0	0	9	28	40	54	73	73	73	73	73	73	73	73	73
10	0	0	0	0	0	19	37	40	70	73	73	73	73	73	73	73	73
11	0	0	0	0	0	7	28	40	52	73	73	73	73	73	73	73	73
12	0	0	0	0	0	0	19	35	40	68	73	73	73	73	73	73	73
13	0	0	0	0	0	0	5	28	40	50	73	73	73	73	73	73	73
14	0	0	0	0	0	0	0	19	35	40	66	73	73	73	73	73	73
15	0	0	0	0	0	0	0	3	27	40	48	73	73	73	73	73	73
16	0	0	0	0	0	0	0	0	18	35	40	63	73	73	73	73	73
17	0	0	0	0	0	0	0	0	1	25	40	46	73	73	73	73	73

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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TABLE 7 - MINIMUM AVERAGE JULY RELEASE FROM HOOVER DAM

SPACE IN LAKE MEAD BELOW ELEVATION 1,229 PLUS SPACE IN LAKE POWELL BELOW ELEVATION 3,700 ON JUL 1	MAXIMUM JULY-JULY FORECAST IN MILLION ACRE-FEET 1/																
	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
MILLION ACRE-FEET	RELEASE IN THOUSANDS OF CUBIC FEET PER SECOND 2/																
2	21	54	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
3	4	36	69	73	73	73	73	73	73	73	73	73	73	73	73	73	73
4	0	19	52	73	73	73	73	73	73	73	73	73	73	73	73	73	73
5	0	2	34	67	73	73	73	73	73	73	73	73	73	73	73	73	73
6	0	0	17	50	73	73	73	73	73	73	73	73	73	73	73	73	73
7	0	0	0	32	65	73	73	73	73	73	73	73	73	73	73	73	73
8	0	0	0	15	47	73	73	73	73	73	73	73	73	73	73	73	73
9	0	0	0	0	30	63	73	73	73	73	73	73	73	73	73	73	73
10	0	0	0	0	13	45	73	73	73	73	73	73	73	73	73	73	73
11	0	0	0	0	0	28	61	73	73	73	73	73	73	73	73	73	73
12	0	0	0	0	0	11	43	73	73	73	73	73	73	73	73	73	73
13	0	0	0	0	0	0	26	59	73	73	73	73	73	73	73	73	73
14	0	0	0	0	0	0	9	41	73	73	73	73	73	73	73	73	73
15	0	0	0	0	0	0	0	24	57	73	73	73	73	73	73	73	73
16	0	0	0	0	0	0	0	7	39	72	73	73	73	73	73	73	73
17	0	0	0	0	0	0	0	0	22	54	73	73	73	73	73	73	73

1/ COLORADO RIVER FORECAST SERVICE VALUE FOR INFLOW TO LAKE MEAD LESS ADJUSTMENT FOR EFFECTIVE STORAGE SPACE IN UPSTREAM RESERVOIRS.

2/ VALUES OF MINIMUM AVERAGE RELEASE ON THESE TABLES WERE CALCULATED ACCORDING TO THE DESCRIPTION GIVEN IN EXHIBIT 1 OF THIS APPENDIX, WITH ONE EXCEPTION: SPACE IN LAKE MEAD AND LAKE POWELL IS TOTALED AND THAT SUM IS TREATED AS IF IT WERE ALL SPACE IN LAKE MEAD.

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Appendix G
AGENCIES' VIEWS AND RESPONSES

Appendix G

AGENCIES' VIEWS AND RESPONSES

This appendix contains all written review comments received during review of the February 1981 draft of this report. The letter requesting comments along with the mailing list is followed by the Corps' responses to each letter of comment when the letter contained questions or raised issues about the study or recommended flood control operating plan.

DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT, CORPS OF ENGINEERS
P. O. BOX 2711
LOS ANGELES, CALIFORNIA 90053

SPLED-HE

10 March 1981

Dear Sir:

The Los Angeles District Corps of Engineers and Lower Colorado Regional Office of Water and Power Resource Service have undertaken a joint study to determine the best flood control operation plan for Hoover Dam. Inclosed is a draft report documenting the evaluation of nine alternative flood control operation plans considered in the study as well as the tentative selection of one of those plans.

This letter seeks to formally request your comments with respect to the study and your views regarding the choice of the most appropriate flood control operating plan. Review of the inclosed report has been requested from the attached list of addressees.

Your comments should be directed to the Los Angeles District and be received by 1 June 1981.

Sincerely,

ROGER C. HIGBEE
Lieutenant Colonel, CE
Acting District Engineer

2 Incl
As stated

3/6/81

HOOVER DAM
MAILING LIST

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Mr. Clyde L. Gould, Manager and Secretary
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Comments and Responses

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United States Department of Agriculture

Soil Conservation Service

Lower CO River RC&D Office
P. O. Box 834
Parker, Arizona 85344

April 20, 1981

Department of the Army
Los Angeles District, Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

Re: Flood Control Operation Plans

Please send us copies of the drafts of the Evaluations of the Alternative Flood Control Operation Plans for the Colorado River Basin and the Hoover Dam, Review of Flood Control Regulations, dated February, 1981.

Thank you.

John F. Colvin Jr./ap

John F. Colvin, Jr.
RC&D Coordinator

NO RESPONSE REQUIRED.

G-11

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
Colorado Bason River Forecast Center
337 North 2370 West
Salt Lake City, Utah 84116

March 19, 1981

Roger C. Higbee
Lieutenant Colonel, CE
Acting District Engineer
P O Box 2711
Los Angeles, California 90053

Dear Lt. Col. Higbee:

The hydrologist in charge, Colorado Basin River Forecast Center recommends that alternative plan no. 1 be adopted and implemented as the flood operation plan for Hoover Dam.

1 The plan possibly should be revised to include operations of the Central Arizona Project at the time that project becomes operational.

2 Manuals and document should include the suggestions by District Engineer of USCOE and Regional Director WPRS.

Sincerely,

Gerald Williams

Gerald Williams
Hydrologist-in-Charge

G-12

Response to letter from U.S. Department of Commerce, National Weather Service dated March 19, 1981.

1. As stated in the report's recommendations, the Hoover Dam flood control operation plan is to be reviewed for appropriateness and relevance after full implementation of the Central Arizona Project.

2. An updated water control manual for Hoover Dam is already under preparation and will be finalized subsequent to the conclusion of this study.

Department Of Energy
Western Area Power Administration
P.O. Box 3402
Golden, Colorado 80401

MAY 29 1981

IN REPLY
REFER TO: A6000

Lieutenant Colonel Roger C. Higbee
Acting District Engineer
Los Angeles District, Corps of Engineers
Department of the Army
P.O. Box 2711
Los Angeles, CA 90053

Dear Colonel Higbee:

As requested by your March 10, 1981 letter, we have reviewed the February 1981 draft report on "Colorado River Basin - Hoover Dam - Review of Flood Control Regulation."

We were pleased to note that the impacts on power operations and energy generation were considered in evaluating the various flood control alternatives. We realize that the stepped release patterns for Hoover Dam were based primarily on the threshold of impending flood damages. Nevertheless, this stepped release pattern will allow greater flexibility in our power marketing program during flood control operations. It should be recognized however, that the August initiation of the winter drawdown period may require special coordination with the Upper Basin to avoid risking the loss of operating flexibility at Glen Canyon Dam under some flood control conditions.

In general, it is our opinion that the report is adequate and comprehensive in both scope and approach in analyzing the flood control problems and many associated impacts on the Lower Colorado River. Thank you for the opportunity to review and comment on this report.

Sincerely,

Robert L. McPhail
Administrator

G-13

NO RESPONSE REQUIRED.

United States Department of the Interior
BUREAU OF INDIAN AFFAIRS
COLORADO RIVER AGENCY
Route 1, Box 9-C
Parker, Arizona 85344

IN REPLY REFER TO

Land Operations - Irrigation
(602) 669-2187

April 7, 1981

Lt Col. Roger C. Higbee
Acting District Engineer,
Los Angeles District, Corps of
Engineers
P. O. Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

We have reviewed your flood control plan and feel that alternate 1 does provide the most feasible and effective operational procedure to meet the requirements for both power and irrigation requirements. We would also recommend that sustained flows above the 28000 CFS be avoided if at all possible because of the detrimental effect on the irrigable land along the river. Sustained flows above 28000 CFS will raise the ground water table in the land and also build up salinity in the soil.

Sincerely,

Walter R Mills
Superintendent

G-14

NO RESPONSE REQUIRED.

United States Department of the Interior
BUREAU OF INDIAN AFFAIRS
PHOENIX AREA OFFICE
P.O. Box 7007
Phoenix, Arizona 85011

IN REPLY REFER TO:
Land Operations-Irrigation
(602) 261-2285 FTS
261-2285 COM

March 27, 1981

Lt Col. Roger C. Higbee
Acting District Engineer,
Los Angeles District, Corps of
Engineers
P.O. Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

We have reviewed your flood control plan and do not wish to make any specific comments at this time. We prefer to allow the individual agencies and Tribes to make their own evaluation and comments concerning the plan. We feel that they are in a better position to see how the plan and its alternatives would affect their localities.

Thank you for providing us a copy of your plan.

Sincerely,

ASSISTANT Area Director

NO RESPONSE REQUIRED.

United States Department of the Interior
BUREAU OF INDIAN AFFAIRS
SAN CARLOS IRRIGATION PROJECT
P.O. Box 456
Coolidge, Arizona 85228

IN REPLY REFER TO

May 5, 1981

Roger C. Higree
Lieutenant Colonel, CE
Acting District Engineer
Department of Army
Los Angeles District Corps of Engineers
P.O. Box 2711
Los Angeles, California 90053

Dear Sir:

Your study of the flood control operation plan of Hoover Dam has been reviewed by personnel in this office. We approve of your conclusions and recommendations.

Ralph Esquerra
Project Engineer

NO RESPONSE REQUIRED.

G-16

United States Department of the Interior

IN REPLY REFER TO
7220 (932)

BUREAU OF LAND MANAGEMENT
ARIZONA STATE OFFICE
3400 VALLEY BANK CENTER
PHOENIX, ARIZONA 85073

June 2, 1981

Department of the Army
Los Angeles District
Corps of Engineers
P.O. Box 2711
Los Angeles, CA 90053

Gentlemen:

We appreciate the opportunity to review and comment on the draft Flood Control Operation Plan for Hoover Dam. We have both concerns and suggestions as explained below.

1 The preferred alternative, which involves water releases of 40,000 cubic feet per second, would have considerable impact on existing recreation developments and activities along and in the Colorado River. These impacts should be better quantified in relation to increased flows, since the existing discussion is rather general. Based on similar flows which occurred during 1980, impacts which should be addressed include flooding of campgrounds at Fisher's Landing, boat-in campground in the Picacho State Recreation Area and beach areas at Riverside Park in Yuma. In addition, the projected flows would disrupt general recreation use along the river and result in cancellation of some organized events, such as the Yuma inner tube race.

The higher flow projections and potential flood hazards are the primary reasons for (1) the relocation of camping outside the floodplain below Imperial Dam, and (2) the termination of residential leases in the same areas. While these flows impact recreation opportunities, they have been anticipated and incorporated into Yuma District recreation plans and management. These would be logical mitigation measures to include in the document.

Sincerely,

Clair M Whitlock
State Director

C-17

Response to letter from U.S. Department of the Interior, Bureau of Land Management, Arizona State Office, June 2, 1981.

1. Large flood control releases called for in any of the alternative flood control operating plans evaluated will have significant impacts with respect to recreational developments and activities along the lower Colorado River. In that these impacts have a relatively small economic value as compared with other factors, such as water conservation, power, and flood damages, the impacts are temporary in nature and are shared by all plans; they would not materially influence the selection of the flood control plan. Hence, a detailed evaluation was not undertaken. It appears, however, that your agency has implemented appropriate mitigation measures in light of the recently increased chances of flood control releases from Hoover Dam.

United States Department of the Interior

IN REPLY REFER TO
7221
C-932.2

BUREAU OF LAND MANAGEMENT

STATE OFFICE
Federal Office Building
2800 Cottage Way
Sacramento, California 95825

MAR 23 1981

Roger C. Highee, Lt. Col., CE
Department of the Army
Los Angeles District, Corps of Engineers
P.O. Box 2711
Los Angeles, Calif. 90053

Dear Colonel Highee:

We have reviewed the Draft Review of Flood Control Regulation and have no comments on the study. The proposed selection of Alternative 1 appears to be reasonable, with Alternative 2 being a close second place.

Sincerely,

Richard F. Johnson
Chief, Division of Resources

G-18

NO RESPONSE REQUIRED.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
AREA OFFICE, ARIZONA - NEW MEXICO
2953 W. INDIAN SCHOOL ROAD
PHOENIX, ARIZONA 85017
August 20, 1981

Col. Gwynn Teague, District Engineer
Corps of Engineers
Dept. of the Army
Los Angeles District
P.O. Box 2711
Los Angeles, California 90053

Dear Col. Teague:

We have reviewed your draft report "Colorado River Basin Hoover Dam, Review of Flood Control Regulation" dated February 1981. As brought out in the report beneficial as well as adverse impacts on fish and wildlife and their associated habitat can be anticipated with the release of sustained high flows.

1 Under past operating conditions winter low flows sometimes drop below that desired for mainteranance and use of aquatic resources associated with the river. A concerted effort should be made to prevent extremely low winter flows. The 4000 cfs flow suggested by the California Department of Fish and Game should be an acceptable minimum.

2 Every effort shou[illegible]ade to hold releases to nondamaging levels and to coordinate rel[illegible]ith periods of low plant growth and wildlife reproduction. Thus, [illegible]gh flows during the spring and early summer months should be reduced to the extent possible.

While adverse impacts can be anticipated with higher flows through the loss of existi[illegible] marshes and backwaters, such impacts may be offset by the formation of new ones.

We recognize the need for increased flood flow releases. The opportunity to review the report is appreciated.

Sincerely,

[illegible] L. Morgan
[illegible] Area Manager

cc:
USFWS, Ecological Services, Phoenix, A[illegible]

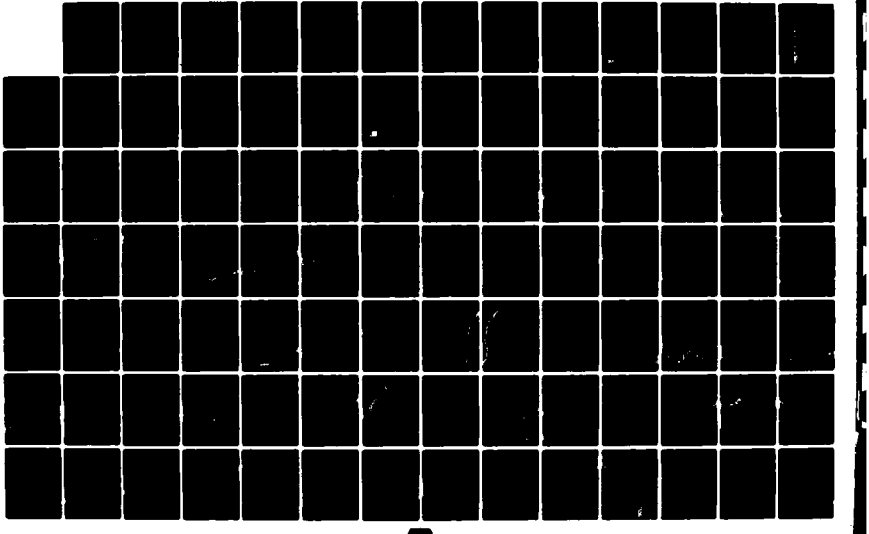
Response to letter from the U.S. Department of the Interior, Fish and Wildlife Service, Area Office, Arizona-New Mexico, dated August 20, 1981.

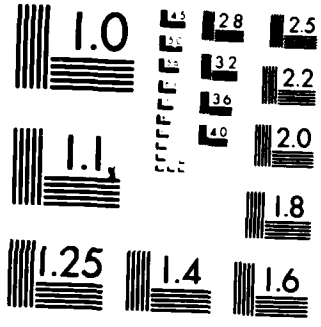
1. The suggested 4000 cubic feet per second minimum winter flow falls w[illegible]hin the normal operating criteria rather than the flood control operation, which, by definition, addresses periods of high flows. It is recommended that further direct coordination with the Bureau of Reclamation on this matter be undertaken.

2. The selected alternative plan is designed to control spring and early summer runoff to the lowest release step or rate considered appropriate within flood control operation.

AD-A132 464 COLORADO RIVER BASIN HOVER DAM - REVIEW OF FLOOD CONTROL REGULATION(U) ARMY ENGINEER DISTRICT LOS ANGELES CALIF JUL 82 4/5

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

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EL PASO, TEXAS 79902

APR 24 1981

Col. Gwynn A. Teague, District Engineer
Corps of Engineers, Los Angeles District
P. O. Box 2711
Los Angeles, California 90053

Dear Col. Teague:

We appreciate the opportunity to review the draft joint report, "Colorado River Basin, Hoover Dam, Review of Flood Control Regulation, February, 1981," provided with your letter of March 10, 1981.

The study was fully coordinated with the International Boundary and Water Commission, including joint meetings with Mexican authorities. The report adequately covers the international considerations.

I am pleased to advise that the U. S. Section concurs in the recommendation that Alternative 1 be adopted and implemented as the flood control operation plan for Hoover Dam. We believe that the implementation of Alternative 1 will provide the best balance between flood control and water supply operations insofar as international considerations are concerned.

We appreciate the opportunity to have participated in the study and to provide comments on the draft report.

Sincerely,

J. [illegible]. Friedkin
Commissioner

cc: Mr. Eugene Hinds
Regional Director
Lower Colorado Region
Water and Power Resources Service

C-20

NO RESPONSE REQUIRED.

BRUCE BABBITT, Governor
Commission
C. GENE TOLLE, Phoenix, Chairman
WILLIAM H. BEERS, Prescott
CHARLES F. ROBERTS, O.D., Bisbee
FRANK FERGUSON, JR., Yuma
FRANCES W. WERNER, Tucson
Director
ROBERT A. JANTZEN
Deputy Director
ROGER J. GRUENEWALD

ARIZONA GAME & FISH DEPARTMENT
2222 West Greenway Road Phoenix, Arizona 85023 942-3000
1420 W. Beale eet, Kingman, Arizona 86401

21, 1981

Lieutenant Colonel Roger C. Higbee
Acting District Engineer
Department of the Army
Los Angeles District, Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

The Arizona Game and Fish Departme: has examined the Draft Review of Flood Control Regulation for the Colorado River below Hoover Dam, dated February 1981, and we offer the following specific comments on the text of the Draft:

1 Page 8, paragraph 1.

The word arthropad should be arthropod.

2 Page 19, paragraph 5.

The term "rare and/or endangered" occurs two times in this paragraph. We recommend the substitution of the term "endangered" or "threatened", as this reflects the terminology currently in use.

The paragraph implies that both peregrine and prairie falcons are classified as threatened or endangered; however, only the peregrine falcon is classified as "endangered".

3 Page 20, paragraph 1.

Bony tail should be one word: bonytail. As well as being designated as "rare" in California, the bonytail chub is federally designated as "endangered" and is classified as Group II (in danger of being eliminated) in Arizona.

In the same sentence, reference is made to the humpback sucker. We recommend that this be changed to razorback sucker which is the commonly accepted name for this species. Addi ly, we suggest it be added that the razorback sucker is also li as Group III (a species whose status may be in jeopardy i foreseeable future) in Arizona.

4 Page 43, Alternative 8.

"The plan would not permit an increase in diversions to MWD, so the entire reduction in storage would be lost to the Gulf of Mexico." Gulf of Mexico should be Gulf of California.

5 Appendix E, page 8, last paragraph.

The current federal list of endangered and threatened wildlife does not include the Tule white-fronted goose, as this paragraph implies.

6 Appendix E, page 13.

Paragraph 1.

As of April 24, 1980, the bonytail chub was officially listed as an endangered species of the U.S. Fish and Wildlife Service.

Paragraph 2.

On May 27, 1980, the Fish and Wildlife Service withdrew the proposal to list the razorback sucker as threatened.

7 Regarding the various alternatives, the Department supports Alternative 6. This alternative allows for the smallest water level fluctuations on Lake Mead during the space-building period between August 1 and January 1. A decrease in the magnitude of water level fluctuations on Lake Mead should help to stabilize the aquatic ecosystem in the lake. According to Table 7, Appendix E, the maximum sustained flows below Hoover Dam allowed by Alternative 6 would be adequate for flood control during all flood frequencies considered. Furthermore, the proposed releases under Alternative 6 would not be substantially different from those proposed under Alternative 1. During sustained flows of 35,000-40,000 c.f.s., we believe that some scouring and associated downstream sedimentation may occur on the riverine portions of the Colorado River below Hoover Dam, however, this would be offset somewhat by the improved water quality and increased marsh

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habitat produced by higher water levels in the backwaters between Davis Dam and Topock Gorge.

Thank you for the opportunity to comment on this proposal.

Sincerely,

Roger J. Gruenewald, Deputy Director

Richard A. Gerhart
Acting Habitat Evaluation Specialist
Ringman Regional Office

RAG:dd

cc: Planning and Evaluation Branch, Phoenix
Don Wingfield, Supervisor, Yuma Regional Office

Response to letter from Arizona Game & Fish Department, dated May 21, 1981.

1-6. Comments 1 through 6 have been incorporated into the text of this report.

7. It is acknowledged that alternative 6 with a January 1 flood control space requirement of 4.5 million acre-feet (MAF) would tend to produce less water surface elevation fluctuation in Lake Mead during the August 1 to January 1 space building period. If the entire difference in January 1 flood control space requirement between alternative 1 (5.35 MAF) and alternative 6 (4.50 MAF) was located in Lake Mead, the difference in water surface elevation would be 6 feet. However, this would be exceedingly unlikely in that credit for effective storage space in upstream reservoirs would tend to minimize differences in actual January 1 water surface elevations in Hoover Dam among the various alternatives.

Selection of alternative 6 instead of alternative 1 would mean foregoing average annual net benefits of $197,000 (see table 5 in main report). In addition, although alternative 6 proved roughly equivalent to alternative 1 in capability of controlling the 1000-year-flood event (appendix A, table A-5), it should be noted that it was significantly less effective for the 333- and 500-year events. Because alternative 6 limits maximum flood control releases to 40,000 cubic feet per second with the exception of uncontrolled spillway discharges, alternative 6 would be less than alternative 1 (maximum release of 73,000 cubic feet per second) in controlling events larger than the 1000-year flood.

STATE OF CALIFORNIA—RESOURCES AGENCY EDMUND G. BROWN JR., Governor

DEPARTMENT OF FISH AND GAME
350 Golden Shore
Long Beach, CA 90802
(213) 590-5113

March 24, 1981

Lt. Colonel Higbee, Acting District Engineer
U. S. Army Corps of Engineers
Los Angeles District
P.O. Box 2711
Los Angeles, CA 90053

Dear Colonel Higbee:

Your letter of March 10, 1981 to Mr. Bruce Eliason of my office formally requested comments by June 1, 1981 with respect to the joint study report "Colorado River Basin, Hoover Dam - Review of Flood Control Regulation" Draft dated February, 1981 prepared by the U. S. Army Corps of Engineers, Los Angeles District and the Lower Colorado Region, Water and Power Resources Service.

Although we plan to provide the Department's review comments and views as to the most appropriate flood control alternative by the requested date, it will be helpful if you would submit the formal request for review to the Director, Department of Fish and Game. The Department's formal response will need to come from the Director and your submittal of the formal request to him will establish appropriate schedules and assignments within the Department. These are necessary in order to obtain a thorough, multi-disciplinary review as to the potential fish and wildlife influences resulting from the proposed action.

Thank you for your consideration in this matter.

Sincerely,

for Fred A. Worthley Jr.
Regional Manager
Region 5

G-23

NO RESPONSE REQUIRED.

STATE OF CALIFORNIA—THE RESOURCES AGENCY

EDMUND G. BROWN JR., Governor

COLORADO RIVER BOARD OF CALIFORNIA
107 SOUTH BROADWAY, ROOM 8105
LOS ANGELES, CALIFORNIA 90012
(213) 620-6460

May 29, 1981

Roger C. Higbee
Lieutenant Colonel, CE
Acting District Engineer
Los Angeles District, Corps of Engineers
Post Office Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

We have reviewed the draft "Review of Flood Control Regulations, Colorado River Basin, Hoover Dam" dated February 1981.

We concur in your selection of Alternative No. 1 as the best flood control operation plan for Hoover Dam. We also concur in your modification to the 1968 flood control operation plan which limits the fall months flood control space-building releases from Lake Mead to a non-damaging level of 28,000 cubic feet per second by extending the drawdown period two additional months.

In addition to the above comments, we also have the following detailed comments on the text of the report, identified by page and paragraph numbers:

1 Page 14, first full paragraph. In addition to encroachment of structures on the flood plain, mention should be made of the encroachment of vegetation, especially in the Yuma area, which also reduces the flood-carrying capacity of the river.

2 Page 18, fourth paragraph. It should be mentioned that because of the extensive growth of vegetation in the floodway at Yuma in recent years, the existing levees are no longer capable of containing their design flows and that a study is currently under way to assess means of solving this problem.

3 Page 20, first full paragraph. In order to present a more accurate and comprehensive description of the apportionment of Colorado River Basin water supply, we recommend that this paragraph be rewritten as follows:

> "The Colorado River Compact of 1922 divided the water between the Upper and Lower Basins with the division point at Lee Ferry, located in northern Arizona near the Utah border. The Compact also divided the states into an Upper Division, consisting of the States of Colorado, New Mexico, Utah, and Wyoming, and a Lower Division consisting of the States of Arizona, California, and Nevada. Each Basin was apportioned the right to beneficial consumptive use of 7.5 million acre-feet (maf) per year from the Colorado River System. In addition, the Lower Basin was given the right to increase its use by 1 maf per year. The Compact states that any required delivery of water to Mexico shall be supplied first from water surplus to the foregoing apportionments (a total of 16.0 maf a year) and that if the surplus is insufficient, the burden of the deficiency shall be borne equally by the Upper and Lower Basins. It provides that the states of the Upper Division will not cause the flow at Lee Ferry to be depleted below 75 maf for any period of 10 consecutive years.
>
> In the 1944 U.S.-Mexican Treaty, the United States agreed to deliver to Mexico a guaranteed 1.5 maf annually from the Colorado River, with an additional 0.2 maf per year to be delivered when there exists a surplus, as determined by the United States. In the event of extraordinary drought, Mexico's allotment is to be reduced in the same proportion that consumptive uses in the United States are reduced.
>
> In addition to the Compact and the Treaty, apportionments of water in the Colorado River Basin are subject to many other documents such as water supply contracts, federal laws, and decrees of the U.S. Supreme Court."

4 Page 20, second full paragraph, and Table 2, page 23. Table 2 presents data as of 1975. There are more recent data available which should be used in lieu of the 1975 data. The uses for the Upper Basin should be increased by about 550,000 acre-feet (the exact figure would depend upon the year finally selected) to account for Colorado River Storage Project reservoir evaporation. Lower Basin uses should be further qualified by a footnote that would state that the uses are subject to being reduced to reflect return flows to the river that are presently unaccounted but which are being quantified through an on-going Bureau of Reclamation study of these unmeasured return flows. All of the data on the table were not available from the source identified in the footnote to the table, and the other sources used should also be identified. Footnote b starts out with a prepositional phrase that is not a sentence and should probably be eliminated.

5 When the changes indicated above are made in Table 2, and are then carried over to the text on page 20, we recommend that a further change be made to the text. Since water supply data for the river usually is referred to in terms of virgin flow at Lee Ferry, we suggest that the flow above Hoover Dam, referred to herein, be separated into flow at Lee Ferry of about 14 maf/yr and tributary flow of about 0.9 maf/yr.

6 Finally, we recommend that the date for full operation of the Central Arizona Project be revised to reflect current schedules, which would be a few years later than the year 1986 stated in this paragraph. We suggest that you contact the Bureau of Reclamation at Boulder City for the current schedule.

7 Pages 21 and 22, Water Quality Section. The Water Quality Section should be rewritten to reflect the current status of (a) the river's salinity levels and reasons therefor, (b) potential salinity control projects, and (c) salinity damages. We suggest that the Bureau of Reclamation's Colorado River Water Quality Office in Denver be requested to provide updated information.

This concludes our comments. Please let me know if you have any questions regarding any of the above comments.

Very truly yours,

M. B. Holburt

Myron B. Holburt
Chief Engineer

cc: Eugene Hinds

Response to letter from Colorado River Board of California, dated May 29, 1981.

1-4. The text of the report has been modified to incorporate comments 1 through 4.

5. The statement in the text of the draft report was factually correct and adequately served to illustrate the desired point; hence no change was made.

6. No change in the text of the report was made because the dates given reflect current schedules for full operation of the Central Arizona Project.

7. The water quality section of the report has been updated as suggested after coordination with the Bureau's Colorado River Water Quality Office.

UPPER COLORADO RIVER COMMISSION

355 South Fourth East Street
Salt Lake City, Utah 84111

May 11, 1981

Mr. Joe Evelyn
Los Angeles District
Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

Dear Mr. Evelyn:

This will confirm our oral conversation of May 4th requesting a 60-day time extension from June 1, 1981 for comments on the "Draft Review of Flood Control Regulations, Colorado River Basin, Hoover Dam." It is our understanding that you will accept comments from Upper Basin interests within the above-mentioned time frame.

I trust that this is your understanding of our conversation at the meeting of the Upper Colorado River Commission's Legal and Engineering Committees, and that no further request or confirmation is required. Please advise if the above is not your understanding.

On behalf of our Legal and Engineering Committees, I wish to thank you for your explanation of the informational review.

Very truly yours,

Paul L. Billhymer
Executive Director

PLB:hiw

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NO RESPONSE REQUIRED.

ROBERT LIST
Governor

DUANE R. SUDWEEKS
Administrator

STATE OF NEVADA
DIVISION OF COLORADO RIVER RESOURCES

Address Reply To
P.O. Box 19060
Las Vegas, Nevada 89119

Telephone (702) 733-7755

Office Address
4220 Maryland Parkway
Building B, Suite 402
Las Vegas, Nevada 89109

June 8, 1981

Lt. Col. Roger C. Higbee
Acting District Engineer
Department of the Army
Los Angeles District, Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

Dear Mr. Higbee:

This is to furnish our comments as requested by your letter of March 10, 1981, which transmitted a draft report documenting the evaluation of nine alternative flood control plans.

Of the alternative flood control operation plans studied, it was the recommendation of the draft report that Alternative 1 be selected. Given the assumptions and associated uncertainties inherent in such a study, we feel Alternative 1 and Alternative 2 to be equally acceptable. We do not, however, find any reason to be critical of the selection of Alternative 1.

We appreciate the opportunity comment.

Sincerely,

for Duane R. Sudweeks
Administrator

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NO RESPONSE REQUIRED.

Nevada Department of Wildlife

ROBERT LIST
GOVERNOR

JOSEPH C. GREENLEY
DIRECTOR

1100 VALLEY ROAD · P.O. BOX 10678 RENO, NEVADA 89520 · TELEPHONE (702) 784-6214

May 21, 1981

Roger C. Higbee
Lieutenant Colonel, CE
Acting District Engineer
Department of the Army
Los Angeles District, Corps of Engineers
P.O. Box 2711
Los Angeles, CA 90053

Dear Colonel Higbee:

The Nevada Department of Wildlife appreciates the opportunity to review and provide comments on Colorado River Basin Hoover Dam - Review of Flood Control Regulations (Draft), February 1981.

The Department of Wildlife is concerned with flood flow management on the Colorado River as it relates to water operations on Lake Mead and Lake Mohave.

It is difficult to identify gains or losses in the value of recreational fishing from the data presented in the various alternatives. Our major interest is in annual and seasonal water elevations and the effect on fish habitat in the littoral zone. We have developed general criteria for management of these shoreline areas that are crucial to production and survival of largemouth bass.

We are aware that no legal recognition was given to fish and wildlife values in the Boulder Canyon Project Act. However, these values have developed and should be given adequate consideration under the Wildlife Coordination Act in any major modification of water operations.

1 We will support any alternative that provides increasing water elevations during late winter, spring and summer seasons and annual stability within maximum and minimum elevation ranges. It appears that these conditions could be often met in trade-off with upper basin reservoirs. The objective is to provide an optimum habitat condition of terrestrial and aquatic vegetation.

2 The review contains no economic assessment of the values of sport fisheries relative to each alternative, and we believe that some attention should be directed to this factor as an integral part of flood flow management.

If you have any questions relative to these concerns, please contact this office at your earliest convenience.

Sincerely,

Joseph C. Greenley
Director

VKJ:pw

cc: State Clearinghouse
Region III
Game Division
Fisheries Division

Response to letter from Nevada Department of Wildlife,
dated May 21, 1981.

1. It is acknowledged that fluctuations in water surface elevation in Lake Mead have a significant impact on terrestrial and aquatic vegetation as well as on sport fisheries. It should be recognized, however, that the major goal in selection of a flood control operating plan is to establish a means of controlling flood inflows to designated rates downstream to permit orderly utilization of the river and its flood plain. All flood control plans, both those considered in this study or any that might be envisioned, have as a common element the evacuation of reservoir space in the fall and winter months to enable the capture and control of spring and early summer runoff. Hence, relatively large fluctuations in water surface elevations are an inevitable result of any flood control operation.

   The alternatives having the smallest January 1 flood control space requirement (4.5 million acre-feet) would tend to have the least overall fluctuation in water surface elevation at Lake Mead. Alternatives with 5.35 million acre-feet of required January 1 storage space would not result in significantly different water surface fluctuations at Lake Mead because of the credit given to available storage space in upstream reservoirs.

2. A detailed economic assessment of the values of sport fisheries relative to each alternative was not undertaken because the differences in water surface fluctuations between the alternatives is relatively small making the magnitude of the economic benefits of sport fisheries unlikely to materially influence selection of the best flood control plan. It is particularly the case because the alternative plans were formulated in an attempt to maximize benefits to the authorized project purposes of flood control, water supply, and power.

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NEW MEXI. TERSTATE STREAM COMMISSION

BATAAN MEMORIAL BUILDING
STATE CAPITOL
SANTA FE, NEW MEXICO 87503

COMMISSIONERS

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S. E. REYNOLDS, Secretary, Santa Fe
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GEORGE BRANTLEY, Carlsbad
JOHN L. GREGG, Las Cruces

LEGAL ADVISER

CHARLES M. TANSEY, Farmington

August 28, 1981

Lieutenant Colonel Roger C. Higbee
Acting District Engineer
Los Angeles District, Corps of Engineers
P O Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

The draft report on Review of Flood Control Regulation, Hoover Dam, dated February, 1981, transmitted by your March 10 letter, has been reviewed and the following comments are offered.

The report recommends the selected plan, Alternative 1, be adopted and implemented as the flood control operation plan for Hoover Dam in lieu of the 1968 regulation. This recommendation by the District Engineer is concurred in by Eugene Hinds, Regional Director, Bureau of Reclamation, Lower Colorado Region.

As we understand, Alternative 1 would modify the 1968 regulation by extending the space-building release period to include the months of August and September. Extension of the space-building releases to include August and September results from lower release rates from Hoover Dam than used in the 1968 regulation. The lower release rates are occasioned by adoption of the objectives of not damaging encroachments in the flood plain below Hoover Dam, which limits release rates to 28,000 cubic feet per second, and of enhancing power generation by limiting space-building releases to the capacity of the power plants; the capacity of the Parker Power Plant is 19,000 cubic feet per second.

1 The longer release period places an unfair risk of subsequent deficiencies in flow on the Upper Colorado River Basin because of provisions of Section 602(a) of Public Law 90-537. Under the documents which constitute the "Law of the River", beneficial consumptive use of waters of the Colorado River is the first priority, while electric power production is the lowest priority. Maximum consumptive use requires full utilization of the conservation capacity of the reservoirs of the Colorado River and increased

power production based on release rates from Hoover Dam limited to power plant capacities cannot be undertaken at the risk of losing water for beneficial consumptive use.

The proposal presented in the draft places too much emphasis on the maximization of power production and protection of construction which has encroached on the Lower Colorado River flood plain, thus risking a negative effect on water supply available to the Upper Basin states.

2 The discussion of water supply on page 20 under the heading "Water Supply - Present and Projected Needs" and Table 2 on page 23, referred to in the discussion on page 20, together give the impression that the Colorado River Compact applies in the Lower Basin only to the flow of the main stem of the Colorado River. The Colorado River Compact apportions the beneficial consumptive use of waters of the entire Colorado River System between the Upper and Lower Basins, as well as providing for future treaty deliveries to Mexico. Table 2 accounts only for uses and exports from the main stem of the Lower Colorado River and all uses in the Upper Basin. A notation to the table states that the data were taken from the Bureau of Reclamation reports "Compilation of Records in Accordance with Article V of the Decree of the Supreme Court of the United States in Arizona vs. California," dated March 9, 1964. This cannot be correct; the cited "Compilation" does not include data on Upper Basin uses. The data in Table 2 for the Upper Basin apparently are taken, not from the aforementioned compilation, but from the Bureau's report entitled "Colorado River System Consumptive Uses and Losses, 1971-1975." That report also includes data on uses from the tributaries in the Lower Basin. The discussion on page 20 and Table 2 should be revised to include all uses of Colorado River System water. In the alternative, Table 2 and page 20 could be revised to make them consistent with the "Compilation" cited.

We appreciate very much the opportunity to comment on the draft report.

Sincerely,

Philip B. Mutz
Interstate Stream Engineer

PBM:bmm

cc: H. P. Dugan
J. R. Riter
Felix Sparks
William McDonald
Calvin Rampton
Dan Lawrence
Floyd Bishop
George Christopulos
Paul Billhymer

Response to letter from New Mexico Interstate Stream Commission, dated August 28, 1981.

1. The extension of the fall space building period by 2 months and limitation on the magnitude of space building releases to a non-damaging rate (28,000 cubic feet per second) were logical and reasonable modifications to the 1968 flood control operating plan in light of current development within the flood plain. Further, the extension of the space building back to August 1 does not place any additional risk with respect to water supply upon the Upper Basin, for the following reasons. First, the required flood control storage space on August 1, (1,500,000 acre-feet) and January 1 (5,350,000 acre-feet) are the same as the 1968 flood control plan. Second, the active storage space in Hoover Dam (27,377,000 acre-feet) is 2,375,000 acre-feet greater than the active storage space in Lake Powell (25,002,000 acre-feet). The significance of this fact is that in a year in which August 1 available storage space is the minimum of 1,500,000 acre-feet (all of which is in Lake Mead), space building requirements for August and September can be almost completely satisfied by releases from Hoover Dam. The October 1 available flood control space requirement of 3,040,000 acre-feet and the September 30 Section 602(a) active storage spilt could be met with the following possible reservoir system status.

Reservoir	Storage Content (acre-feet)	Available Storage Space (acre-feet)
Hoover	24,670,000	2,708,000
Powell	24,670,000	333,000
Flaming Gorge	Full	0
Fontenelle	Full	0
Blue Mesa	Full	0
Navajo	Full	0

Any available storage space in reservoirs upstream from Lake Powell is directly creditable against the 333,000 acre-feet shown in the table. Normally there would be far more available storage space than 333,000 acre-feet in Lake Powell, plus the upstream reservoirs by October 1 in order to begin building space for the next runoff season.

Under the authorizing legislation (Boulder Canyon Project Act), flood control and river regulation have first priority in terms of establishing the operation of Hoover Dam. Water supply and power are second and third priority, respectively. The stepped releases called for by alternative 1 are flood control releases, which happen to be beneficial for both power production and consumptive use of water. Additionally, flood releases are made only in response to a forecast of inflow, which is updated monthly that indicates the release is necessary.

2. Table 2 of the main body of the report has been updated and revised.

Gordon E. Harmston
Executive Director
Dept. of Natural Resources

Scott M. Matheson
Governor

DIVISION OF WATER RESOURCES

Suite 300
231 East 400 South
SALT LAKE CITY, UTAH 84111
Tel: (801) 533-5401

Daniel F. Lawrence
Director

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Delta
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Farron
(Upper Colorado)

Roy P. Urie
Cedar City
(Lower Colorado)

September 3, 1981

Lt. Col. Roger C. Higbee, Acting District Engineer
Department of the Army
Los Angeles District, Corps of Engineers
Post Office Box 2711
Los Angeles, CA 90053

Dear Colonel Higbee:

We have examined the February 1981 "Colorado River Basin-Hoover Dam-Draft Review of Flood Control Regulation", and do not feel we can support the recommended plan. Our principal objections lie not so much with the analytical procedures used as with the basic assumptions.

Water conservation and flood control were the principal purposes for which Hoover Dam was constructed, and the use of water for generation of hydroelectric power was clearly made subservient (See Article IV (b) of the Colorado River Compact and Section 6 of the Boulder Canyon Project Act). Although the basis for the recommended plan in the draft review is ostensibly flood control, it is apparent that the release steps and timing are chosen with power plant capacities in mind.

1 Section 602 (a) of Public Law 90-537 is, of course, the factor which makes releases at Hoover Dam important to the Upper Basin States. When storage in Lake Powell is greater than storage in Lake Mead, releases from Lake Mead can trigger releases from Lake Powell. Under normal circumstances this would not be critical. It is conceivable, however, that a situation could arise in which an overestimate of flood control releases required at Hoover Dam would cause releases from Lake Powell which, due to consecutive dry years, could not be recouped.

2 Under the recommended plan, flood control releases from Hoover Dam will be initiated earlier in the year than under the 1968 plan, thus increasing the chances of excessive releases. The report gives as reasons for the proposed changes in operation increased power generation and less likelihood of damages to structures which have encroached on the flood plain.

We feel that both of these reasons are legitimate and desirable for Lower Basin interests, but can be supported by Utah only if the Upper Basin water supply is guaranteed to be unaffected by the damage. If the Lower Basin wishes to protect residents illegally and inadvisable using the flood plain, and wishes to increase their revenues from hydroelectric power generation, they should be free to do so, but not at the expense of the Upper Basin.

The major issue for Utah associated with the Corps of Engineers recommended flood control operation plan is no different than that discussed and debated at length over the past several years with the Bureau of Reclamation and Lower Basin interests when early releases from Lake Mead were suggested. Utah's position was formally presented in a letter from Governor Matheson to Commissioner Higgenson (copy attached), and this position is unchanged. We still feel that the concept of Upper Basin "credits" is eminently equitable and workable.

3 In closing, it is generally agreed by all parties that diversions for the Central Arizona Project, scheduled to begin in 1985, will greatly reduce the flood regulation problem, since water demands on Lake Mead storage will be significantly increased. It does not seem particularly compelling to us to attempt to permanently change the 1968 regulations to cope with this short-term *situation, particularly when such action could be detrimental to* Upper Basin interests, and when it has a legitimizing influence on admittedly illegal encroachment into the flood plain.

We appreciate the opportunity of commenting on this proposal.

Sincerely,

Daniel F. Lawrence

Daniel F. Lawrence
Director

STATE OF UTAH
OFFICE OF THE GOVERNOR
SALT LAKE CITY
84114

SCOTT M. MATHESON
GOVERNOR

January 20, 1981

Mr. R. Keith Higginson, Commissioner
Water and Power Resources Service
Department of the Interior
Washington, D.C 20240

Dear Commissioner Higginson:

Because the filling of Lake Powell has given the appearance of *water sufficiency in the Colorado River Basin*, there have been strong attempts in recent months to allow Lower Basin reservoirs to be operated in such a manner as to maximize power generation while simultaneously eliminating possible damage to developments which have encroached on the flood plain along the Lower Colorado River. These attempts have culminated in a new reservoir operation plan described in a December 11, 1980 letter from Eugene Hinds, Director of the Lower Colorado Region, Water and Power Resource Service. At a meeting on the same day in Las Vegas, you agreed that comments on this plan, if submitted prior to January 31, would be considered before finalization. We most definitely do want to comment on the proposed plan.

We believe the plan proposed by Mr. Hinds is seriously flawed in terms of both law and equity. The legal basis for the releases is purported to be flood control, and the flood control regulations under which Hoover Dam has been operated for 25 years are claimed to be now supplanted by a document titled "Field Working Agreement between Department of Interior, Water and Power Resources Service, Department of the Army, Corps of Engineers, regarding flood control operation of Hoover Dam and Lake Mead, Colorado River, Nevada-Arizona." A field working agreement does not appear to be a very solid legal foundation where there is concerted opposition from more than half the parties involved.

Further, even a cursory examination of the Field Working Agreement reveals that the effective release rates are based in large part on power pilot capacities and on avoiding damage to developments along the river which, because of a lack of State local, and federal controls have been allowed to encroach on the flood plain. Neither of these factors would seem to meet the requirements for releases under Article III (e) of the Colorado River Compact.

On an equity basis, the proposed plan of operation is even more of a failure. The storage equalization provisions of Section 602 (a), Public law 90-537, will result in the Upper Basin releasing from Lake Powell one-half of any shortage resulting from a miscalculation of early releases from Lake Mead. If the Upper Basin stood to profit in any way from these early releases, this might not be unjust. But Utah and the Upper Basin stand to gain nothing from early releases from Lake Mead, we stand only to lose.

We do, however, recognize the benefits of efficient power generation, particularly in these days of fuel scarcity and high energy costs. Also, we would not want to stand in the way of attempts to minimize flood damages, no matter how strongly we question the advisability of these developments being when they are. For these reasons, we have supported the idea of storage credits for the Upper Basin, whereby if early releases are made from Lake Mead and if these releases do not result in a shortage requiring equalization, nobody suffers. If the water supply was over-estimated significantly, and early releases were made on a basis of these estimates, then the Lower Basin might have to take a shortage. Since it is the Lower Basin alone that would profit from the early releases, this solution of storage credits appears eminently equitable. Mr. Hinds has recommended eliminating this method of accounting, and we strongly oppose such an action.

In conclusion, we feel that Utah has diligently and openly worked with the Water and Power Resources Service and the other Colorado River Basin States to develop a plan of operation that would address the problems, but yet would be both legal and equitable. We feel that the plan proposed in the December 11 letter from Mr. Hinds meets neither of these requirements.

Sincerely,

Governor

Response to letter from State of Utah, Division o Water Resources, dated September 3, 1981.

1. The equalization of active storage between Lake Powell and Lake Mead on September 30 of each year called for by Section 602(a) of Public Law 90-537 in conjunction with the recommended flood control operation plan impose no practical det to the water supply of Upper Basin interests for the followi ns. First, the extension of the fall space buildin oy 2 months and limitation on the magnitude of spac ng releases to a non-damaging rate (28,000 cubic feet per .) were logical and reasonable modifications to the 1968 flood control operating plan in light of current development within the flood plain. Further, the extension of the space building back to August 1 does not place any additional risk with respect to water supply upon the Upper Basin for the following reasons. First, the required flood control storage space on August 1, (1,500,000 acre-feet) and January 1 (5,350,000 acre-feet) are the same as the 1968 flood control plan. Second, the active storage space in Hoover Dam (27,377,000 acre-feet) is 2,375,000 acre-feet greater than the active storage space in Lake Powell (25,002,000 acre-feet). The significance of this fact is that in a year in which August 1 available storage space is the minimum of 1,500,000 acre-feet (all of which is in Lake Mead), space building requirements for August and September can be almost completely satisfied by releases from Hoover Dam. The October 1 available flood control space requirement of 3,040,000 acre-feet and the September 30 Section 602(a) active storage split could be met with the following possible reservoir system status.

Reservoir	Storage Content (acre-feet)	Available Storage Space (acre-feet)
Hoover	24,670,000	2,708,000
Powell	24,670,000	333,000
Flaming Gorge	Full	0
Fontenelle	Full	0
Blue Mesa	Full	0
Navajo	Full	0

Any available storage space in reservoirs upstream from Lake Powell is directly creditable against the 333,000 acre-feet shown in the table. Normally there would be far more available storage space than 333,000 acre-feet in Lake Powell, plus the upstream reservoirs by October 1 in order to begin building space for the next runoff season.

Of course, space building, following a single relatively dry year would be no problem in that the reservoir system would start out with more space than 1.5 million acre-feet on August 1 because of lack of enough runoff to fill all the reservoirs.

2. The stepped flood control releases called for by the selected operation plan are also beneficial to both consumptive use of water and power production. The flood control releases are made only in response to a monthly updated forecast of inflow which indicates that available storage space is not capable of containment. In addition, current Colorado River average annual runoff upstream from Lake Mead is approximately 15 MAF versus 13 MAF of uses, yielding about 2 MAF of surplus annually. It appears prudent to place emphasis on maximum utilization of this surplus in generating pow and fostering consumption and at the same time minimizing flood damages.

3. Corps of Engineers' policy and regulations provide clear guidance with respect to development of water control plans. Corps' regulations state, "Thorough analysis and testing studies will be made as necessary to establish the optimum water control plans possible within the prevailing constraints. Necessary actions will be taken to keep approved water control plans up-to-date. For this purpose, plans will be subject to continuing and progressive study by personnel in field offices of the Corps of Engineers."

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

State Engineer's Office

BARRETT BUILDING CHEYENNE, WYOMING 82002

August 12, 1981

Roger C. Higbee
Lieutenant Colonel
Department of the Army
Los Angeles District, Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

1 As requested in your letter of March 10, 1981, which accompanied the February 1981 Draft, Colorado River Basin, Hoover Dam, Review of Flood Control Regulation, we are submitting our comments with respect to the review. Alternative 2, which has been recommended for adoption, is described as a modified version of the 1968 operation plan with the major modifications being in the rate and duration of the space-building releases. Lower release rates have been incorporated in the modified plan in order to protect developments which have encroached on the flood plain of the river below Hoover Dam. The new release rates based on power plant capacities and additional two month space-building release period also have the effect of increasing hydro-electric power production from the Lower Division's mainstem plants.

2 The earlier and longer release period, which is necessary in order to vacate flood control space at the lower rate of release, places the full risk of miscalculation upon the Upper Basin because of the provisions of Section 602(a) of Public Law 90-537, as well as increasing the risk because releases begin before accurate runoff forecasts can be made. Increasing power production by basing release rates on power plant capacities cannot be done at the expense of water conservation because, according to the "Law of the River", beneficial consumptive use of the water of the Colorado is the first priority of use while electric power production is the lowest priority use. 3

4 We are concerned that the proposal presented in the Draft Review was drafted with too much emphasis placed on maximization of power production at the expense of water conservation and could have a negative effect upon the water supply of the Upper Basin States. Thank you for the opportunity to express our concern with the proposal presented in the draft.

Sincerely,

George L. Christopulos

GEORGE L. CHRISTOPULOS
State Engineer

GLC/llw
cc: See Attached Sheet

G-34

cc: Paul Billhymer, Executive Director
Upper Colorado River Commission
355 South Fourth East Street
Salt Lake City, Utah 84111

Steve Reynolds
State Engineer
Bataan Memorial Bldg.
Santa Fe, New Mexico 87501

Calvin L. Rampton
800 Walker Bank Bldg.
Salt Lake City, Utah 84111

Felix Sparks
7900 West 23rd Avenue
Lakewood, Colorado 80215

Floyd A. Bishop
P. O. Box 53
Cheyenne, Wyoming 82001

Dan Budd
P. O. Box 769
Big Piney, Wyoming 83113

Response to letter from State of Wyoming, State Engineer's Office, dated August 12, 1981.

1. Alternative 1, which retains the same January flood control space requirement of 5.35 million acre-feet, was selected as a result of this study.

2. The extension of the fall space building period by 2 months and limitation on the magnitude of space building releases to a non-damaging rate (28,000 cubic feet per second) were logical and reasonable modifications to the 1968 flood control operating plan in light of current development within the flood plain. Further, the extension of the space building back to August 1 does not place any additional risk with respect to water supply upon the Upper Basin for the following reasons. First, the required flood control storage space on August 1, (1,500,000 acre-feet) and January 1 (5,350,000 acre-feet) are the same as the 1968 flood control plan. Second, the active storage space in Hoover Dam (27,377,000 acre-feet) is 2,375,000 acre-feet greater than the active storage space in Lake Powell (25,002,000 acre-feet). The significance of this fact is that in a year in which August 1 available storage space is the minimum of 1,500,000 acre-feet (all of which is in Lake Mead), space building requirements for August and September can be almost completely satisfied by releases from Hoover Dam. The October 1 available flood control space requirement of 3,040,000 acre-feet and the September 30 Section 602(a) active storage split could be met with the following possible reservoir system status.

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Fontenelle	Full	0
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Navajo	Full	0

Any available storage space in reservoirs upstream from Lake Powell is directly creditable against the 333,000 acre-feet shown in the table. Normally there would be far more available storage space than 333,000 acre-feet in Lake Powell, plus the upstream reservoirs by October 1 in order to begin building space for the next runoff season.

3. Under the authorizing legislation (Boulder Canyon Project Act), flood control and river regulation have first priority in terms of establishing the operation of Hoover Dam. Water supply and power are second and third priority, respectively. The stepped releases called for by alternative 1 are flood control releases, which happen to be beneficial for both power production and consumptive use of water. Additionally, flood releases are made only in response to a forecast of inflow, which is updated monthly that indicates the release is necessary.

4. The selected flood control plan for Hoover Dam does not impact adversely on the water supply of the Upper Basin. The flood control plan prescribes the orderly and controlled release of floodwaters during situations in which the Colorado River reservoir system is facing inflows beyond its capacity to store. The selected plan retains only 282,000 acre-feet of inviolate controlled flood control storage in a reservoir system with a total capacity in excess of 57 million acre-feet.

ELLIS & BAKER, P.C.
ATTORNEYS AT LAW
SUITE 720
2645 EAST CAMELBACK ROAD
PHOENIX ARIZONA 85016
(602) 956-6576

R. J. ELLIS
WILLIAM D. BAKER
ROBERT S. LYNCH
ROBERT S. PORTER
DOUG C. NELSON
SCOTT E. HINGLEY
PAUL R. ORME

May 29, 1981

Lt. Col. Roger C. Higbee, CE
Acting District Engineer
Los Angeles District,
Corps of Engineers
P.O. Box 2711
Los Angeles, CA 90053

Re: Draft EIS on Flood Control
Regulation at Hoover Dam

Dear Colonel Higbee:

We have reviewed the draft EIS on Hoover Dam Flood Regulation and have no substantive comments to offer at this time. We note that the Arizona Water Commission, now the Department of Water Resources, has supported the proposal, alternative one, that is recommended in the draft EIS over the eight alternatives. We would appreciate receiving a copy of the final EIS.

Would you also have noted for your records that Mr. R. J. Ellis and Mr. William D. Baker, both on your mailing list for distribution of the draft can be reached through the mail at our new offices indicated on the letterhead.

Sincerely,

Robert S. Lynch
for
ELLIS & BAKER, P.C.

RSL/kms

G-36

NO RESPONSE REQUIRED.

Department of Public Works

Public Services Building
401 South Fourth Street
Las Vegas, Nevada 89101
(702) 386-4621

GRANVILLE M. BOWMAN
Director of Public Works

May 28, 1981

Lt. Colonel Roger C. Higbee
Acting District Engineer
Department of the Army
Los Angeles District, Corps of Engineers
P.O. Box 2711
Los Angeles, CA 90053

SPLED - HE HOOVER DAM FLOOD CONTROL OPERATION PLAN

We have reviewed the February 1981 draft of the Colorado River Basin Hoover Dam Review of Flood Control Regulation report. We concur with your conclusion and recommend that Alternate I is the best flood control operation plan for Hoover Dam.

It is suggested that whichever strategy is chosen, it will have to be reviewed in detail once the Central Arizona Project begins operation. Most public concern we are familiar with seems to center around a desire to minimize daily water level fluctuations downstream of the Dam. Of course the Las Vegas Valley area is most concerned about reliable, continuous electric power. The economy of this area is extremely
1 dependent upon the tourist-gaming industry. Finally, changes in the drainage watershed standard project flood conditions, especially in the Las Vegas Valley area, might be considered. From 1970 to 1980 the metropolitan population has grown from 226,000 to 470,000.

COMMISSIONERS
Manuel J. Cortez, Chairman • David B. Canter, Vice-Chairman
Thalia Dondero, Jack R. Petrolo, R.J. "Dick" Ronzone, Woodrow Wilson, Bruce L. Woodbury
Bruce W. Spaulding, County Manager • Joseph C. Denny, Assistant County Manager

This has resulted in more paving for homes, businesses, roads, etc. which intern contributes more storm water runoff to Lake Mead.

We are pleased to have been invited to review the study.

GRANVILLE M. BOWMAN
DIRECTOR OF PUBLIC WORKS

BY: Joe Dorbin
JOE DORBIN, P.E.
Chief Flood Control & Development Engineer

cc: G.M. Bowman

Response to letter from Clark County, Nevada, Department of Public Works, Las Vegas, Nevada, dated May 28, 1981.

1. The selected flood control operation plan for Hoover Dam is adequate to handle the increased runoff resulting from urbanization in the Las Vegas area.

Las Vegas Valley Water District

May 28, 1981

Lieutenant Colonel Roger C. Higbee
Acting District Engineer
Department of the Army
Los Angeles District Corps of Engineers
P. O. Box 2711
Los Angeles, CA 90053

Dear Colonel Higbee:

This will acknowledge receipt of your letter of March 10, 1981 transmitting a copy of the February 1981 draft, Colorado River Basin/ Hoover Dam, Review of Flood Control Regulation. We have reviewed the document and have no comments to offer.

We appreciate the opportunity to review the report and request that this office receive a copy of the report when it becomes final.

Sincerely,

Donald L. Paff
General Manager

DLP:jl

NO RESPONSE REQUIRED.

G-38

3700 WEST CHARLESTON BOULEVARD
LAS VEGAS, NEVADA 89153 • (702) 870-2011

Department of Water and Power the City of Los Angeles

TOM BRADLEY
Mayor

Commission
RICARDO R. GUTIERREZ, President
JOHN J. GUARRERA, Vice President
JAMES B. MURPHY
SARA C. STEVELMAN
HERBERT C. WARD
JUDITH K. DAYTON, Secretary

LOUIS H. STEWART, General Manager and Chief Engineer
PAUL H. LANE, Chief Engineer of Water Works and Assistant Manager
JAMES L. MILLER, Chief Electrical Engineer and Assistant Manager
NORMAN J. FORTIER, Chief Financial Officer

June 1, 1981

Lt. Col. Roger C. Higbee, CE
Acting District Engineer
Department of the Army
Los Angeles District, Corps of Engineers
P.O. Box 2711
Los Angeles, California 90053

Dear Lieutenant Colonel Higbee:

In response to your letter dated March 10, 1981, my staff has reviewed the nine alternative flood control plans and agree with your selection of plan one as the recommended alternative.

1 We support Metropolitan Water District's suggestion to improve the channel capacity below Hoover Dam to 35,000 cfs. This would provide more flexibility in the operation of Hoover Power Plant and increase the overall water and power benefits.

2 In addition, the assumed unit cost of energy used in your comparison of the nine alternatives appears to be much too low at 30 mills per kwh. Our estimates, which are based on the escalation of oil fuel prices between now and 1985, indicate that a range of 60 to 95 mills per kwh is more realistic.

We appreciate this opportunity to submit our comments.

Sincerely,

Raymond C. Burt

RAYMOND C. BURT
Engineer in Charge
of Operation and Maintenance

Water and Power Conservation ... a way of life

111 North Hope Street, Los Angeles, California ☐ Mailing address: Box 111, Los Angeles 90051
Telephone (213) 481-4211 Cable address: DEWAPOLA

Response to letter from the City of Los Angeles, Department of Water and Power, City of Los Angeles, dated June 1, 1981.

1. We concur that a higher non-damaging channel capacity downstream from Hoover Dam would provide more flexibility in making releases for flood control and power production. The objective of this study deals with operating criteria at Hoover Dam rather than investigation of potential downstream improvements.

2. The unit cost of energy of 30 mills per kwh used in the study reflects an estimate of the average replacement cost of energy throughout the Hoover Dam service area. Actual replacement costs for energy may be higher or lower in different parts of service area depending on the alternative energy source, e.g., oil or coal generation, Colombia or Missouri intersystem transfers, et al.

The Metropolitan Water District of Southern California

Office of the General Manager

June 24, 1981

Lt. Col. Roger C. Higbee
Acting District Engineer
Los Angeles District
Corps of Engineers
P.O. Box 2711
Los Angeles, California 90053

Dear Colonel Higbee:

Hoover Dam Flood Control

Your letter of March 10, 1981, invited our comments on the draft report, "Colorado River Basin, Hoover Dam, Review of Flood Control Regulation," dated February 1981. We apologize for having missed the June 1 deadline for submitting comments and appreciate the time extension given by a member of your staff.

We concur in your selection of Alternative 1 as the best flood control operation plan for the immediate future. We note that you intend to review the plan after the Central Arizona Project becomes fully operational. We would like to suggest that your future review include the ideas and comments expressed below in this letter.

As a general comment, the priorities in the Boulder Canyon Project Act give the flood control function preference over the water supply and power production functions. However, it is recognized in the report (p. 51) that "Because Hoover is a multipurpose dam, water conservation, power production, recreation, and maintenance of the natural environment, as well as flood control, must be given adequate consideration in the development of a flood control operation plan."

We suggest that the studies for your scheduled review of the flood control plan include realistic estimates of future values of water and power as well as flood damages. In the studies for the draft report, the flood damages were extrapolated from 1979 to 1989 values based on estimated changes in development of the flood plain. For this same period, the water supply and power production benefits were held constant at $30 per acre-foot and 30 mills per kilowatt-hour, respectively.

1111 Sunset Boulevard, Los Angeles, Calif. / Mailing address: Box 54153, Los Angeles, Calif. 90054 · Telephone: (213) 626-4282

C-40

The average annual water supply and power production benefits for the Lower Basin are large, compared to the average annual flood damages. Annual water benefits amount to about $290 million and power benefits to about $180 million. Annual flood damages, on the other hand, are only about $150,000.

The studies of the several alternatives show only small percentage variations in water and power benefits. Consequently, the differences in benefits between Alternative 1 and each of the other alternatives are small compared to the absolute values of the benefits. Because of this, comparisons of the alternatives are sensitive to small errors in determining the benefits. Comparisons of flood damages are not as sensitive to error since they exhibit relatively large variations compared to their smaller absolute values.

In the post-CAP era, there will be a greater variation in Lower Basin water demands between years of normal water supply and surplus water supply. Metropolitan's use of Colorado River water could vary from its basic priority of 550,000 acre-feet per year (less California Indian water rights) to as much as the full capacity of its Colorado River Aqueduct--1.2 million acre-feet per year--in years when surplus water is available. This contrasts with our present annual use of about 800,000 acre-feet for both normal and surplus water supply conditions. This greater variation in water demand will affect the future regulation of Lake Mead reservoir.

Thank you for the opportunity to comment on your operating plan. If we can be of further help in explaining the ideas expressed in this letter, we would be pleased to do so.

Very truly yours,

for Evan L. Griffith
General Manager

CEH:cas

cc: Mr. Myron B. Holburt, Chief Engineer
Colorado River Board of California
107 South Broadway, Room 8103
Los Angeles, California 90012

OFFICE OF THE FLOODPLAIN ADMINISTRATOR
MOHAVE COUNTY
301 West Beale Street
Kingman, AZ 86401

28 May 1981

District Engineer
Dept of the Army
Los Angeles District
Corps of Engineers
P.O. Box 2711
Los Angeles, Ca.

Re: Colorado River Basin
Hoover Dam - Review of Flood
Control Regulation - Draft
February 1981

Dear Sir:

I have reviewed the draft report of the nine alternative flood control operation plans for the Colorado River Basin and concur with your findings, Plan One would be the most beneficial plan for the lower Colorado River Basin.

Sincerely,

James J. Tucker

NO RESPONSE REQUIRED.

San Bernardino County
FLOOD CONTROL DISTRICT
825 East Third Street · San Bernardino, CA 92415 · (714) 383-1665

C. J. Di PIETRO, Flood Control Engineer

COUNTY OF SAN BERNARDINO
ENVIRONMENTAL
PUBLIC WORKS AGENCY

JOHN M. BERNARD
Agency Administrator

March 25, 1981

File: 6-600/1.00

Dept. of the Army
Los Angeles District
Corp of Engineers
P. O. Box 2711
Los Angeles, CA 90053

Attention: Mr. Roger C. Higbee

Re: Zone 6, Colorado River,
Hoover Dam Outflow

Gentlemen:

The District is in receipt your letter dated March 10, 1981 with regards to a draft report documenting the evaluation of 9 alternative flood control operation plans for Hoover Dam. As of this date, due to our present workload, we have been unable to complete review of referenced subject; you may expect our reply in approximately three weeks.

Should you have any further questions concerning this matter, please contact Mr. Allan J. Kielhold, Chief, Water Reosurces Division at (714) 383-2388.

Very truly yours,

C. J. DI PIETRO, Flood Control Engineer

By Ruben V. Montes
Ruben V. Montes
Asst. Flood Control Engineer
Planning - Engineering

RVM:AJK:mjs

G-42

NO RESPONSE REQUIRED.

Southern California Edison Company

P. O. BOX 800
2244 WALNUT GROVE AVENUE
ROSEMEAD, CALIFORNIA 91770

L. D. HAMLIN
MANAGER OF POWER CONTRACTS

TELEPHONE
(213) 572-2197

June 2, 1981

Mr. Roger C. Higby, LTC CE
Acting District Engineer
U.S. Army Corps of Engineers
Los Angeles District
P.O. Box 2711
Los Angeles, CA 90053

Dear Mr. Higby:

Subject: Flood Control Regulation - Hoover Dam

Per your request, we have reviewed the draft report dated February, 1981, and respectfully offer the following comments.

Southern California Edison Company basically agrees with your recommended implementation of Alternate No. 1 as the best compromise among those studied. Hoover's multi-purpose nature dictates that, at a minimum, the preferred plan not erode the benefits currently available to all users of Lake Mead water and Hoover power.

Although Alternates 2 and 9 provide for increased power generation potential, Edison recognizes that the priority uses of Hoover for water conservation and flood control require a reasonable trade-off with potential economic benefits. Alternate 1, we believe, accomplishes this trade-off in a fair and equitable manner.

1 It was noted, however, that the summary (Page 52, Item H) states that upstream storage could serve in lieu of Hoover's dedicated function for flood control. Edison's concern is such continual use could conceivably result in less water available for power generation (in later years) than Alternate 1 proposes. Verification of the intended implementation of Item H would be helpful.

C-43

NO RESPONSE REQUIRED.

If you have any questions regarding these comments, please contact Julius L. Bognar, of my staff, at (213) 572-4381. The opportunity to comment on this report is appreciated.

Sincerely,

L D Hamlin

L. D. Hamlin

Response to Southern California Edison Company letter dated June 2, 1981.

1. Item H was part of a summary of the major features of the selected flood control plan. Item H states "Available storage space in Lake Powell and effective storage space in other upstream reservoirs could be counted in lieu of space in Lake Mead." The purpose of this feature is to account for available storage space in reservoir upstream from Hoover Dam, thereby preventing the necessary release of water stored in Hoover Dam. The net result of including this feature is increased water supply and power production for the system with no detrimental impact on flood control objectives.

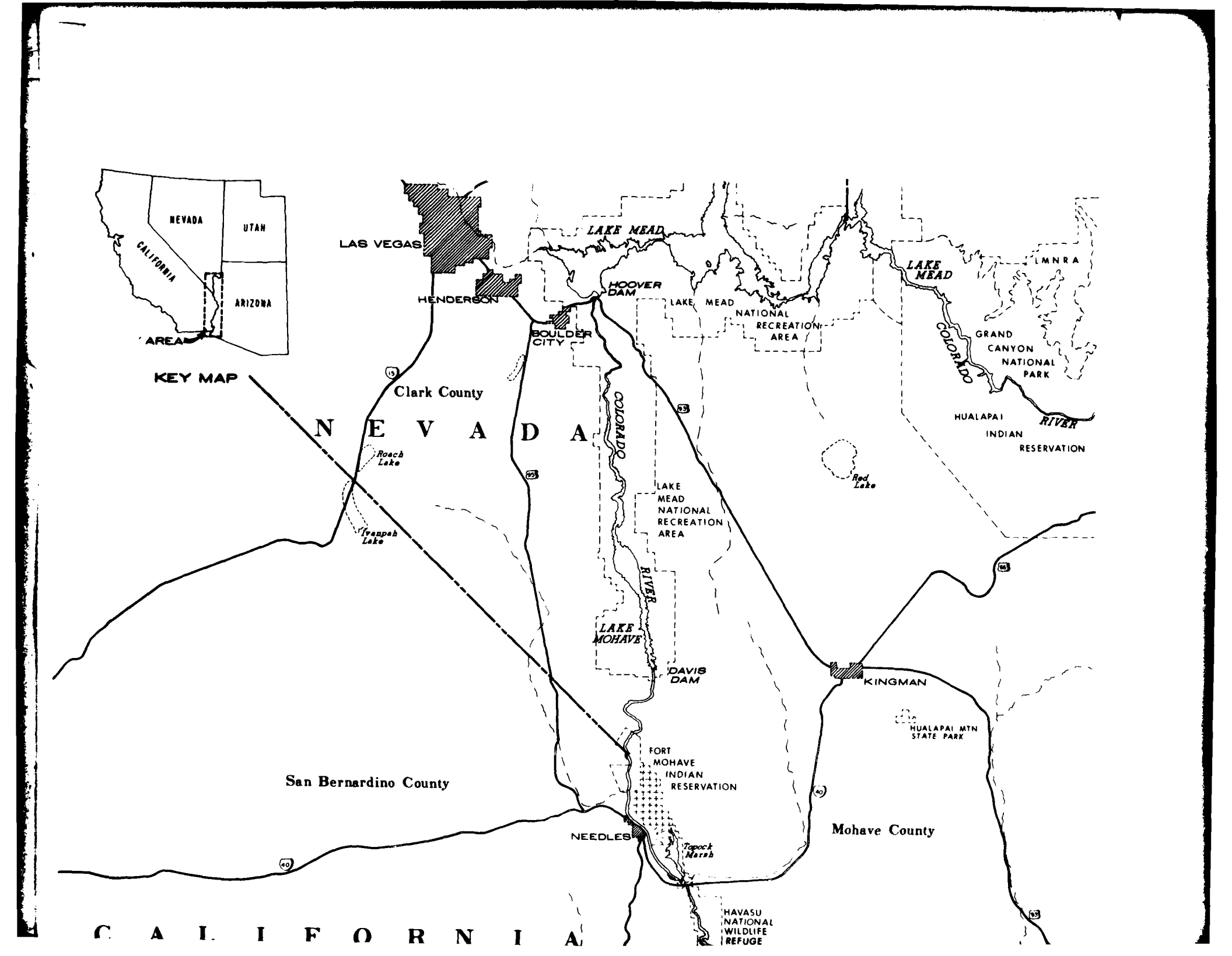
BUREAU OF RECLAMATION MAPS

BUREAU OF RECLAMATION MAPS

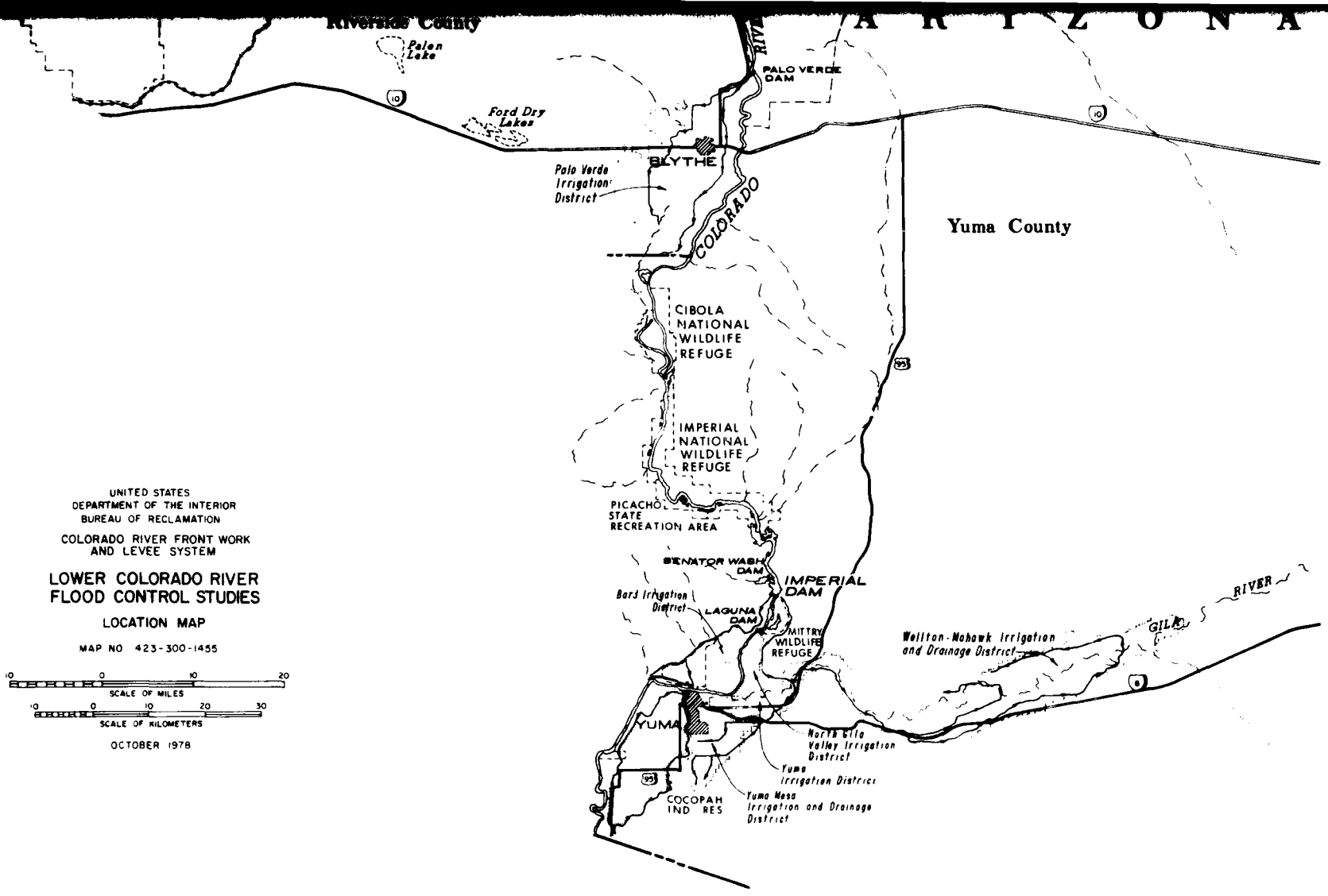
CONTENTS

423-300-1455 Lower Colorado River Flood Control Studies, Location Map.

423-300-1412 through 1434 (23 Sheets) Colorado River Flood Control Series, 1978, Colorado River, Davis Dam to International Boundary.


NEVADA
UTAH
CALIFORNIA
ARIZONA
AREA
KEY MAP
LAS VEGAS
HENDERSON
BOULDER CITY
LAKE MEAD
HOOVER DAM
LAKE MEAD NATIONAL RECREATION AREA
LAKE MEAD
LMNRA
COLORADO
GRAND CANYON NATIONAL PARK
HUALAPAI INDIAN RESERVATION
RIVER
Clark County
N E V A D A
Roach Lake
Ivanpah Lake
COLORADO
RIVER
LAKE MEAD NATIONAL RECREATION AREA
Red Lake
LAKE MOHAVE
DAVIS DAM
KINGMAN
HUALAPAI MTN STATE PARK
FORT MOHAVE INDIAN RESERVATION
San Bernardino County
Mohave County
NEEDLES
Topock Marsh
HAVASU NATIONAL WILDLIFE REFUGE
C A L I F O R N I A


HUALAPAI MTN STATE PARK
FORT MOHAVE INDIAN RESERVATION
San Bernardino County
Mohave County
NEEDLES
Topock Marsh
HAVASU NATIONAL WILDLIFE REFUGE
C A L I F O R N I A
LAKE HAVASU
LAKE HAVASU CITY
LAKE HAVASU STATE PARK
Bristol Lake
Cadiz Lake
Danby Lake
CHEMEHUEVI INDIAN RESERVATION
PARKER DAM
H.N.W.R.
ALAMO LAKE
Bill Williams River
ALAMO DAM
AQUEDUCT
HEADGATE ROCK DAM
PARKER
COLORADO RIVER
COLORADO RIVER INDIAN RESERVATION
JOSHUA TREE NATIONAL MONUMENT
Riverside County
A R I Z O N A
Palen Lake
PALO VERDE DAM
Ford Dry Lakes
BLYTHE
Palo Verde Irrigation District
COLORADO
Yuma County
CIBOLA NATIONAL WILDLIFE REFUGE
IMPERIAL NATIONAL WILDLIFE REFUGE
UNITED STATES



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER FRONT WORK
AND LEVEE SYSTEM

LOWER COLORADO RIVER FLOOD CONTROL STUDIES

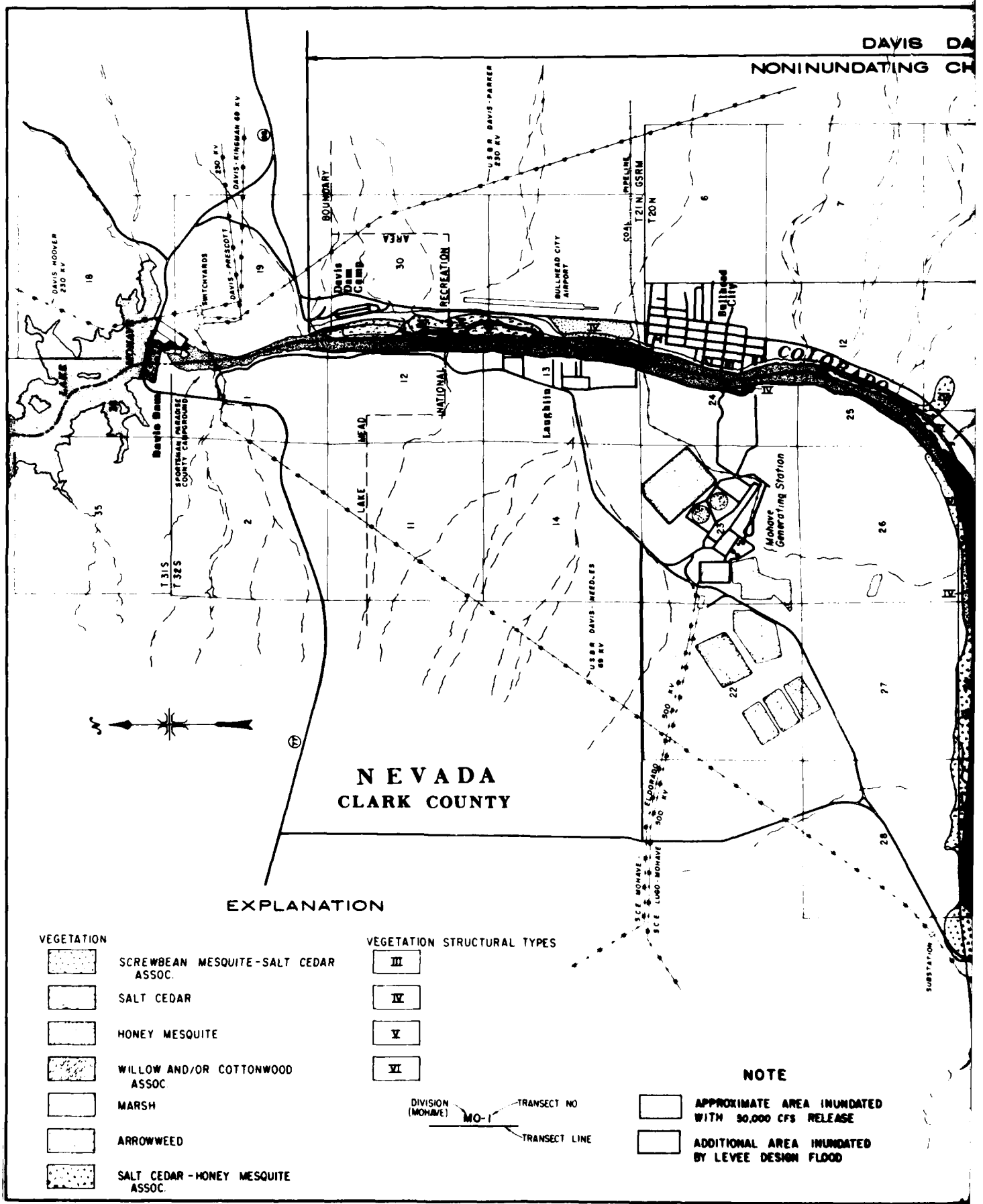
LOCATION MAP

MAP NO 423-300-1455

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SCALE OF MILES

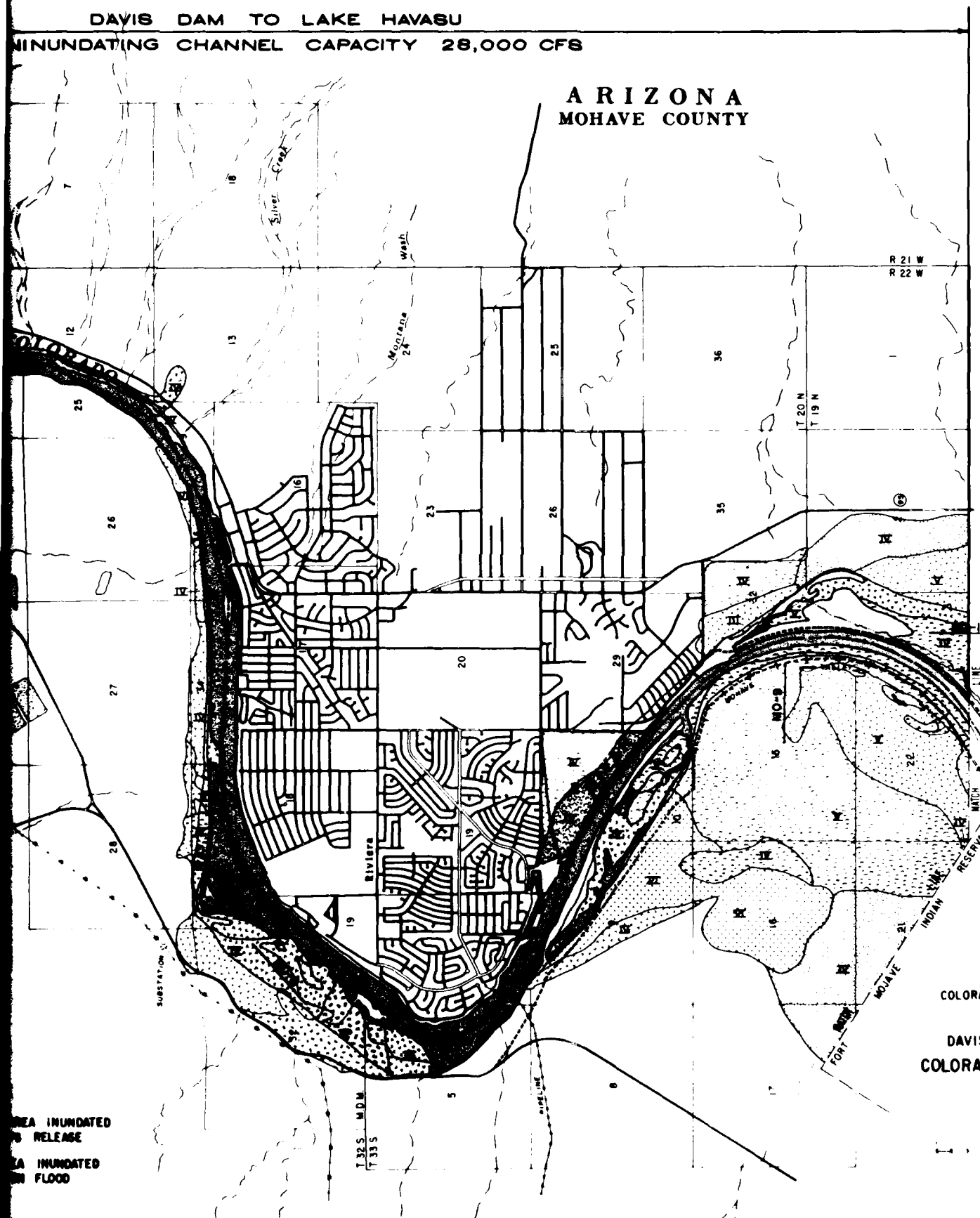
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OCTOBER 1978


DAVIS DA
NONINUNDATING CH
COLORADO
NEVADA
CLARK COUNTY
Davis Dam Camp
RECREATION AREA
Bullhead City
BULLHEAD CITY AIRPORT
Laughlin
Mohave Generating Station
LAKE MEAD
NATIONAL
BOUNDARY
SWITCHYARDS
SCREWBEAN MESQUITE COUNTY CAMPGROUND
T 31 S
T 32 S
T 21 N, GSRM
T 20 N
EXPLANATION
VEGETATION
SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
SALT CEDAR
HONEY MESQUITE
WILLOW AND/OR COTTONWOOD ASSOC.
MARSH
ARROWWEED
SALT CEDAR-HONEY MESQUITE ASSOC.
VEGETATION STRUCTURAL TYPES
III
IV
V
VI
DIVISION (MOHAVE)
MO-1
TRANSECT NO
TRANSECT LINE
NOTE
APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE
ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

DAVIS DAM TO LAKE HAVASU

INUNDATING CHANNEL CAPACITY 28,000 CFS



REA INUNDATED
RELEASE

A INUNDATED
FLOOD

UNITED STATES
DEPARTMENT OF THE
BUREAU OF RECLA

COLORADO RIVER FRONT WORK

COLORADO

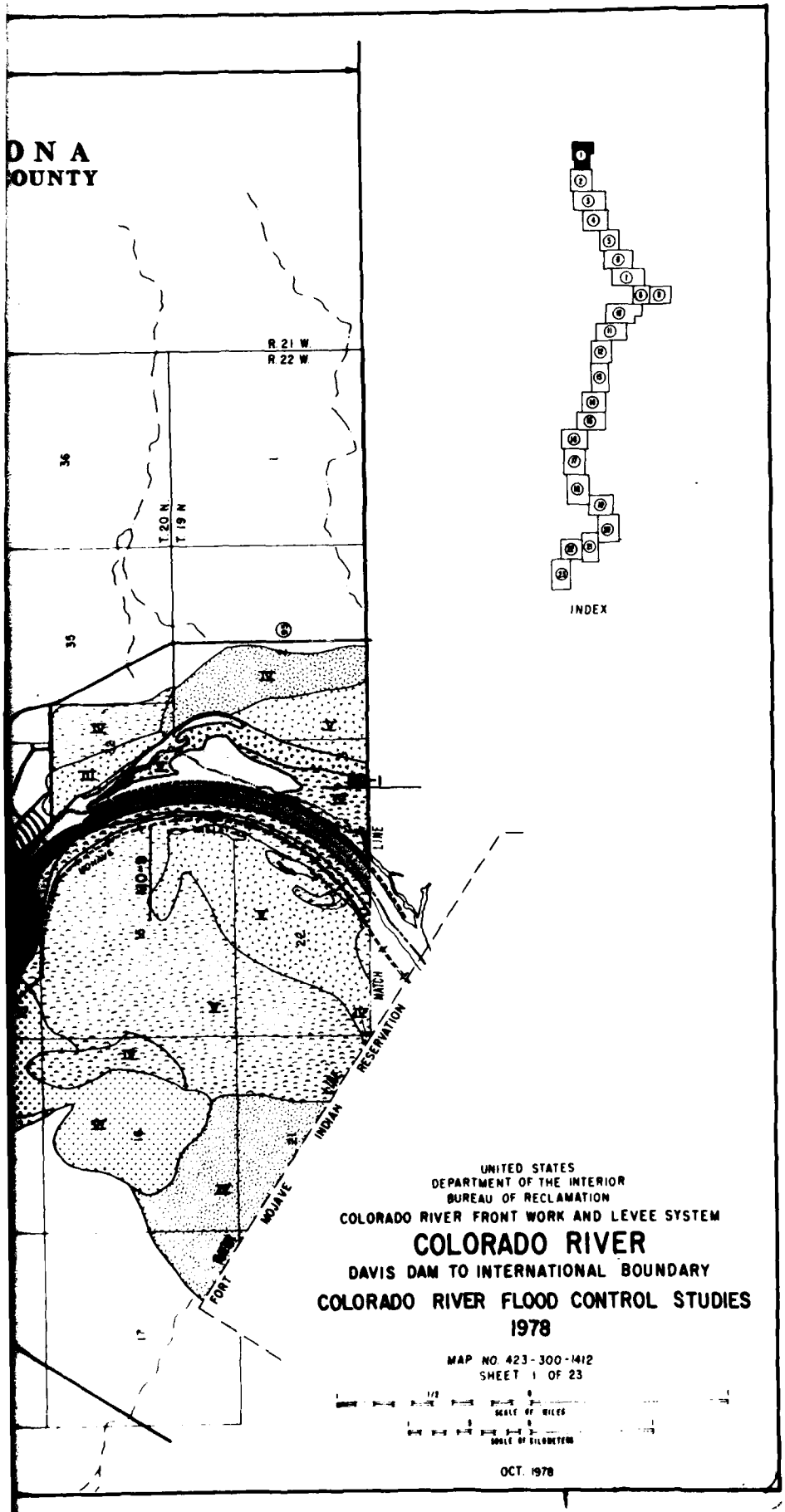
DAVIS DAM TO INTERNATI

COLORADO RIVER FLOOD

1978

MAP NO 423 300-
SHEET 1 OF

OCT 1978



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

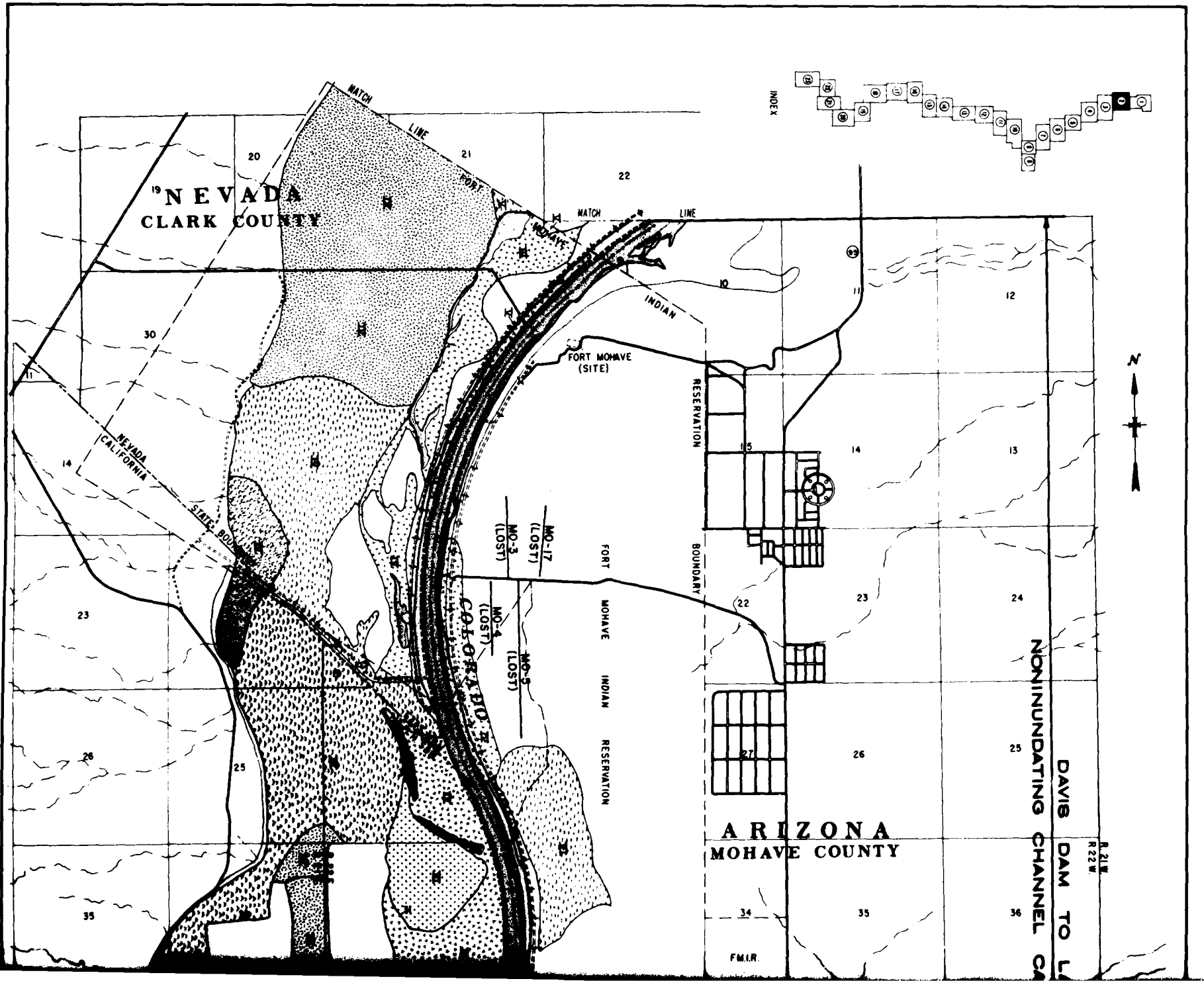
COLORADO RIVER FLOOD CONTROL STUDIES
1978

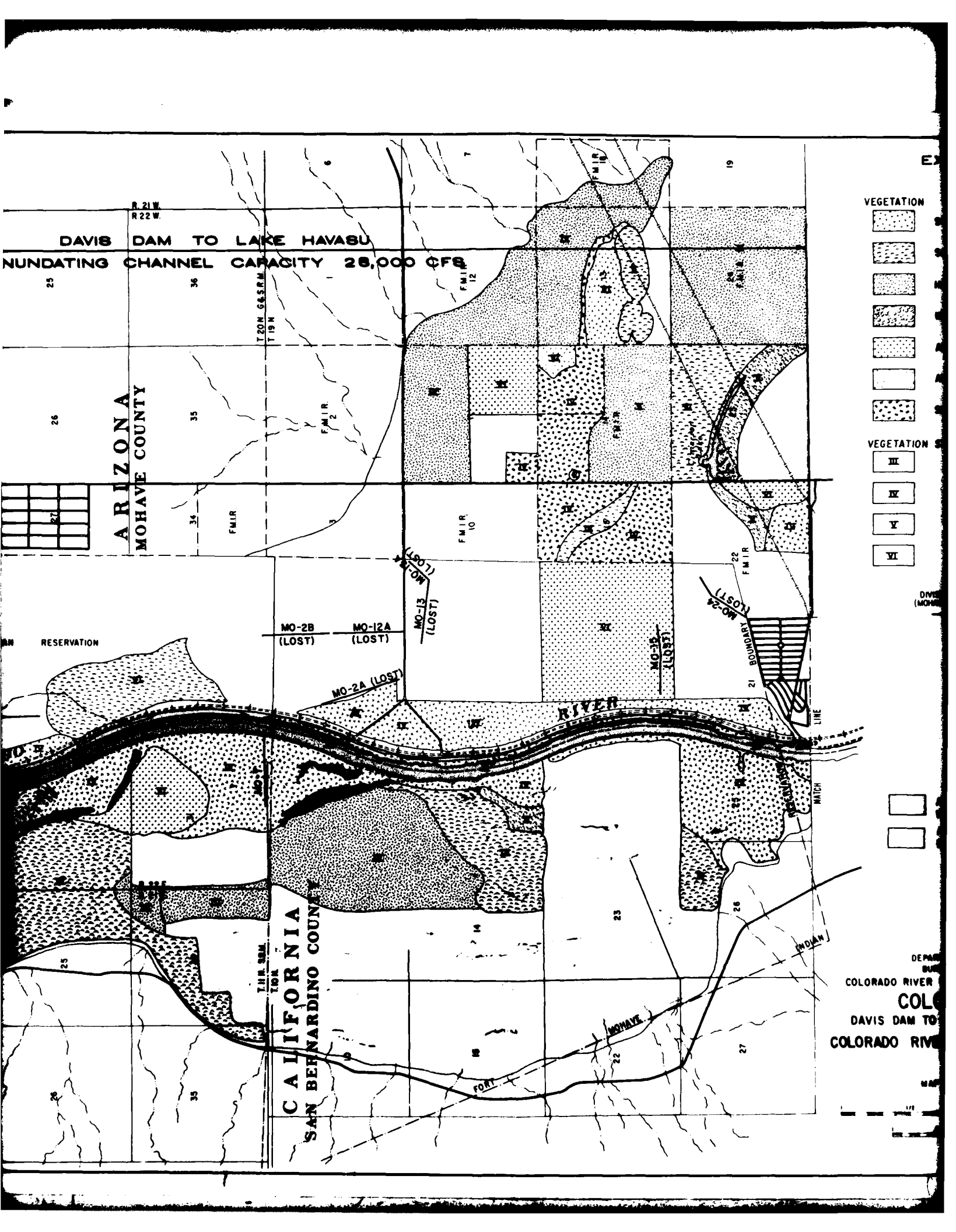
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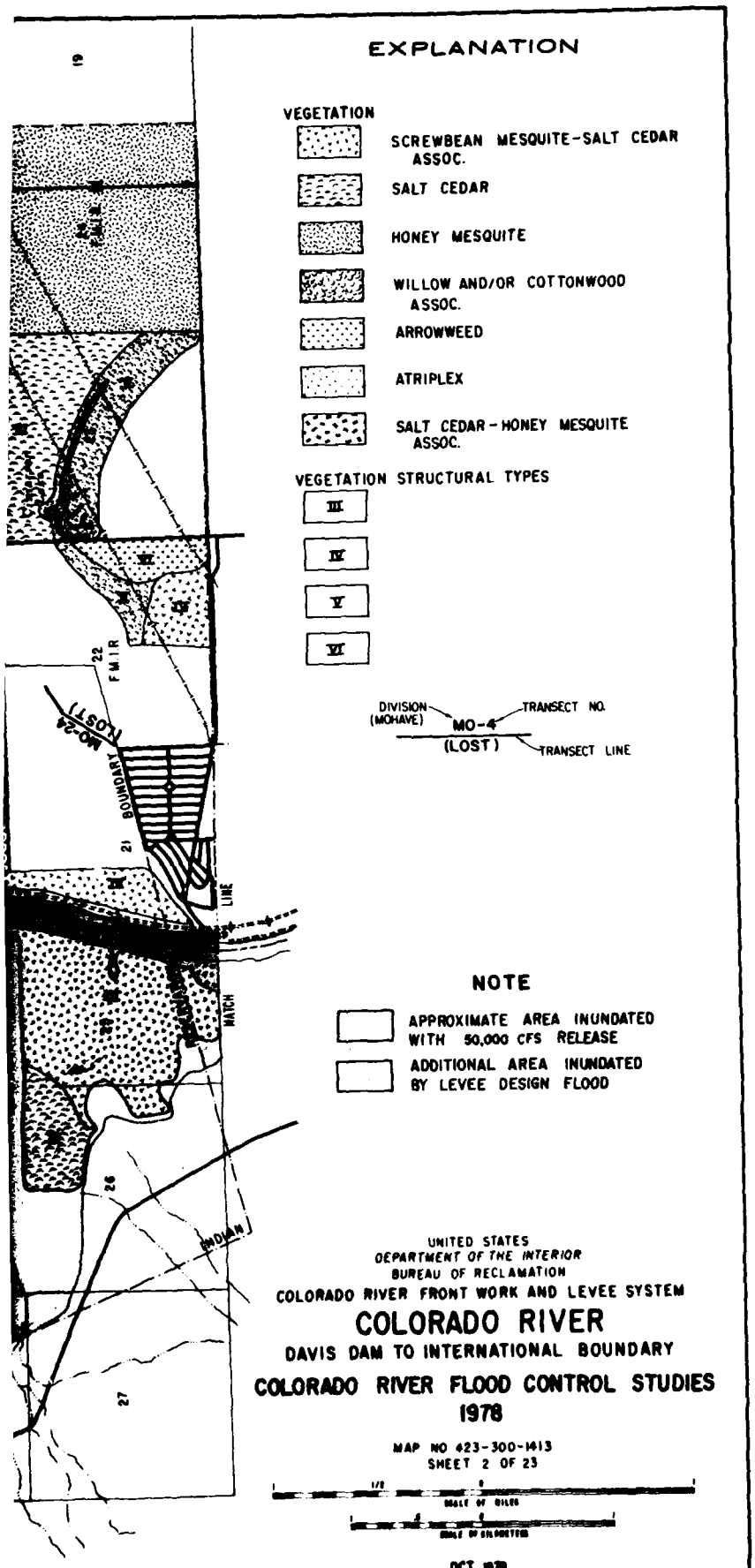
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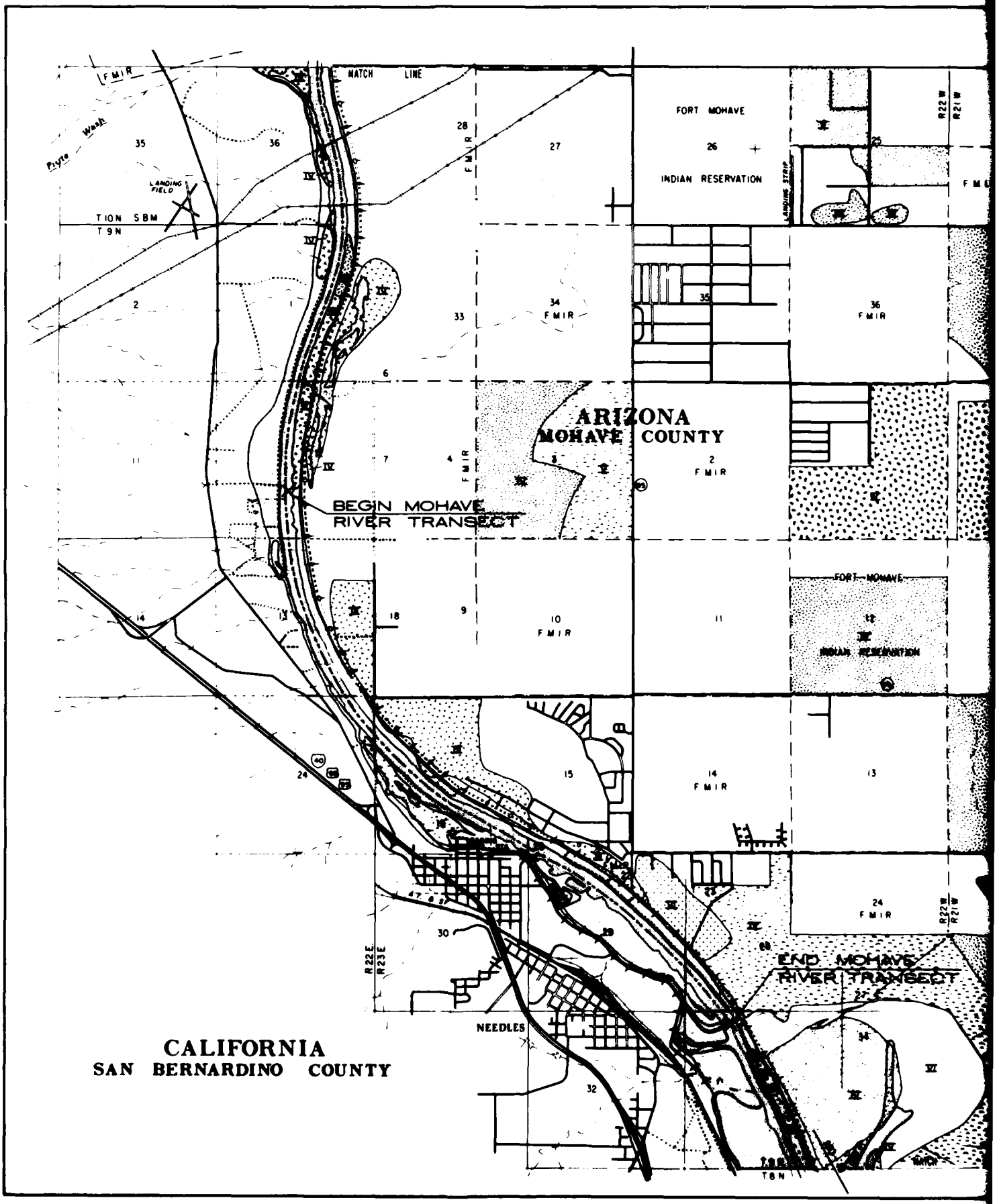
SCALE OF KILOMETERS

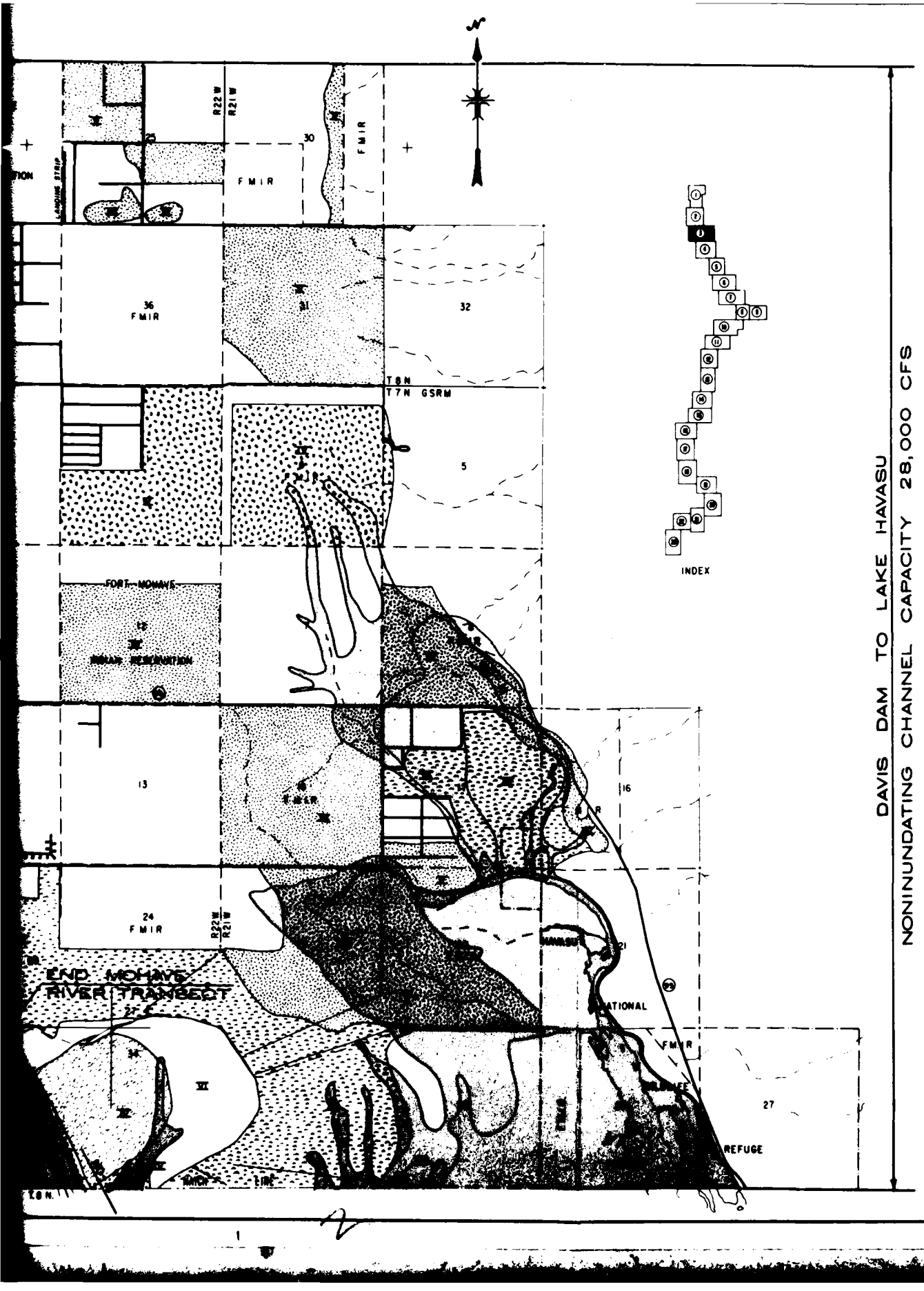
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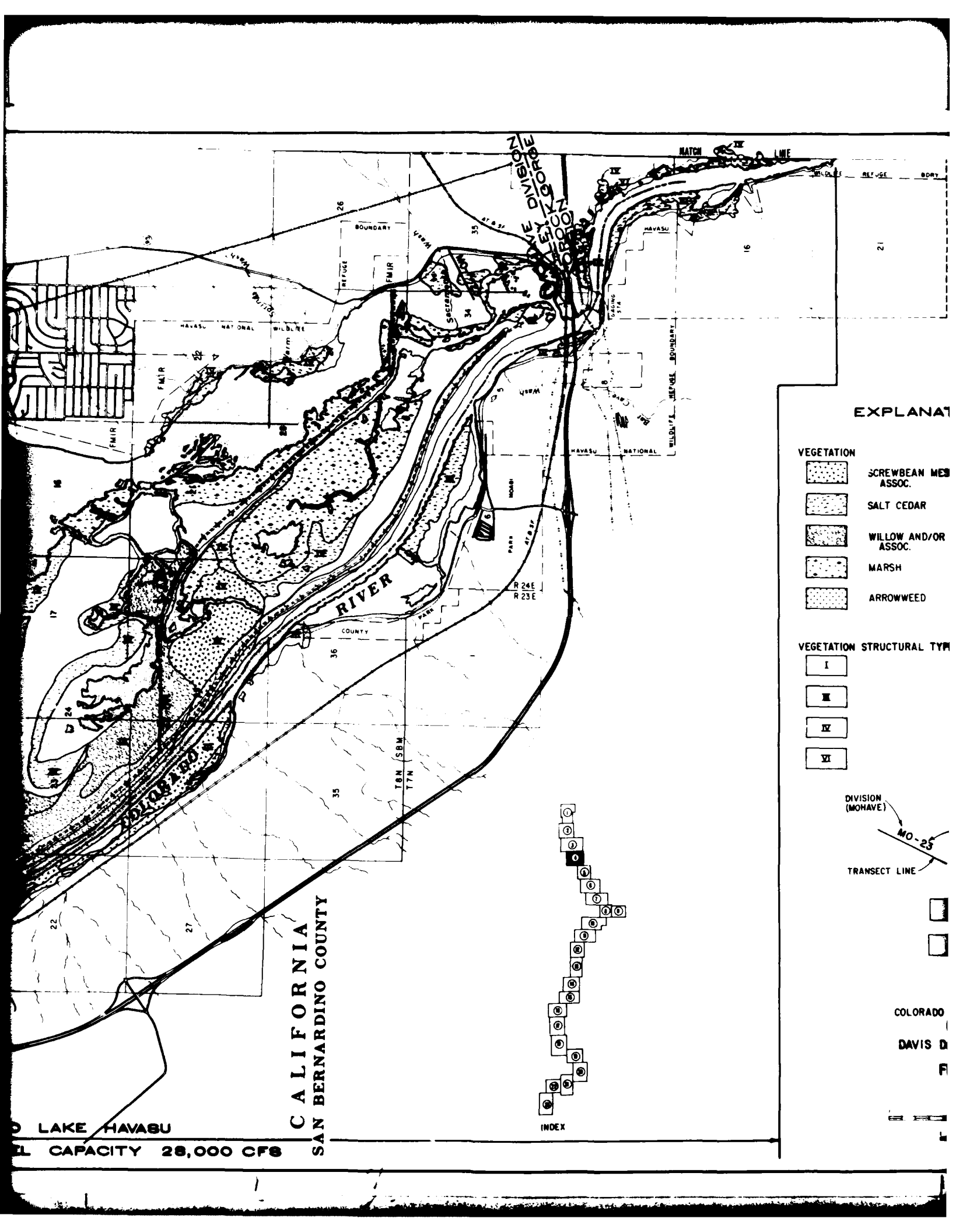
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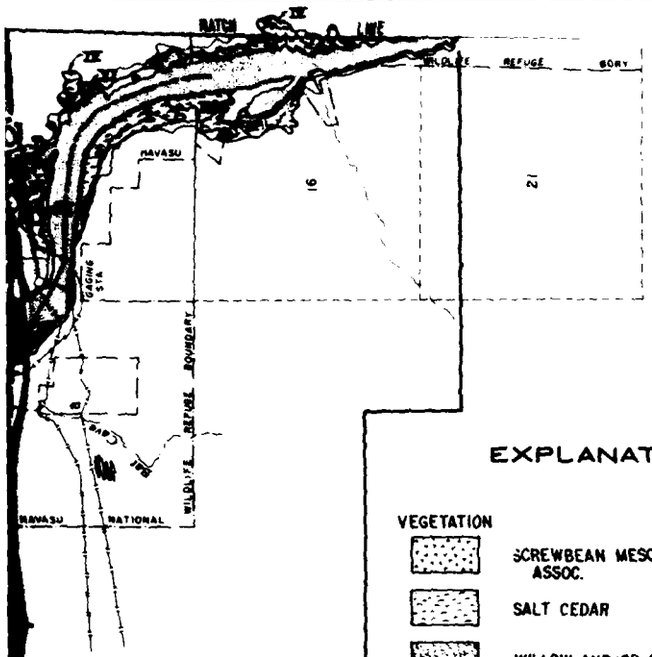
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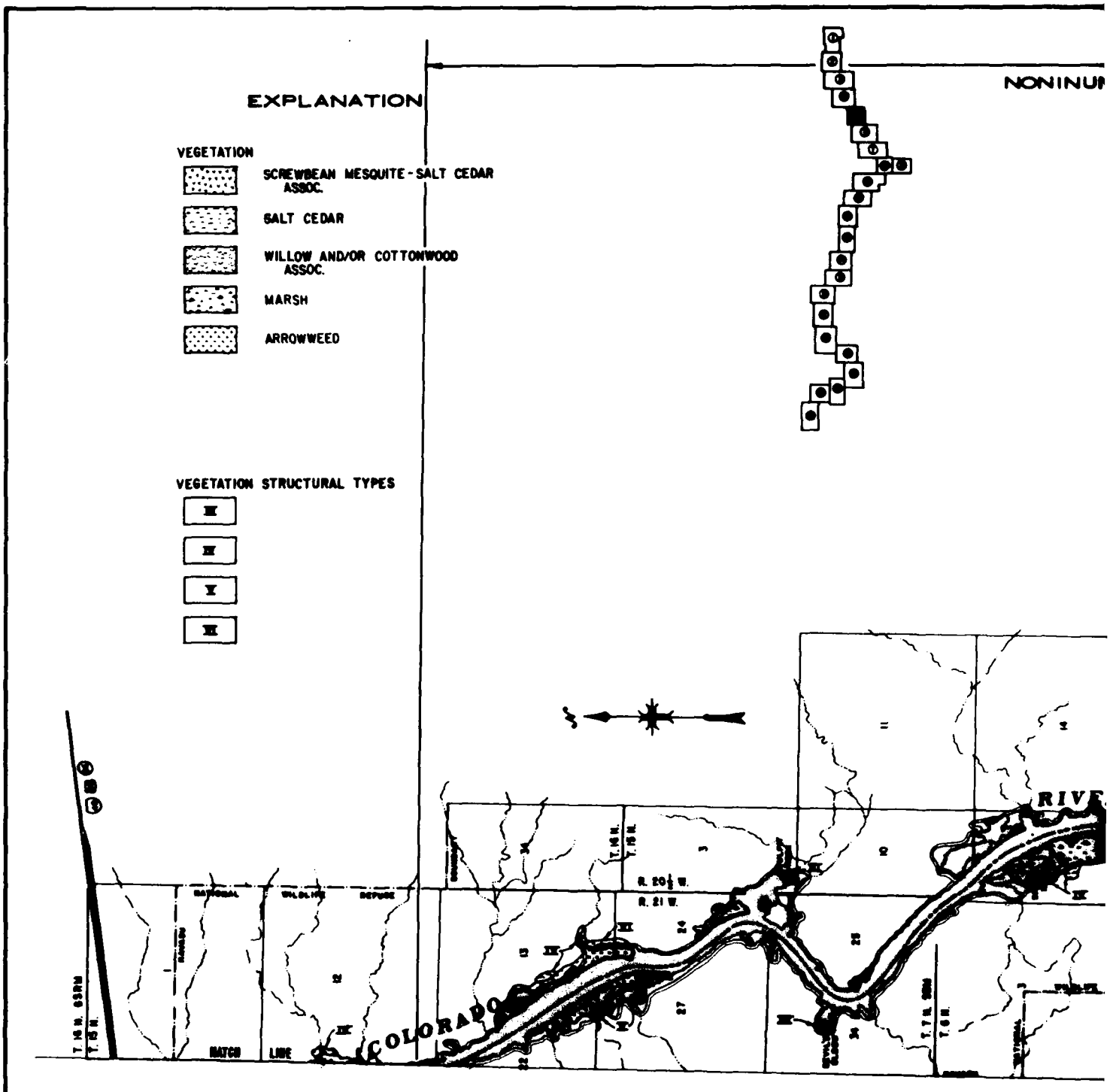
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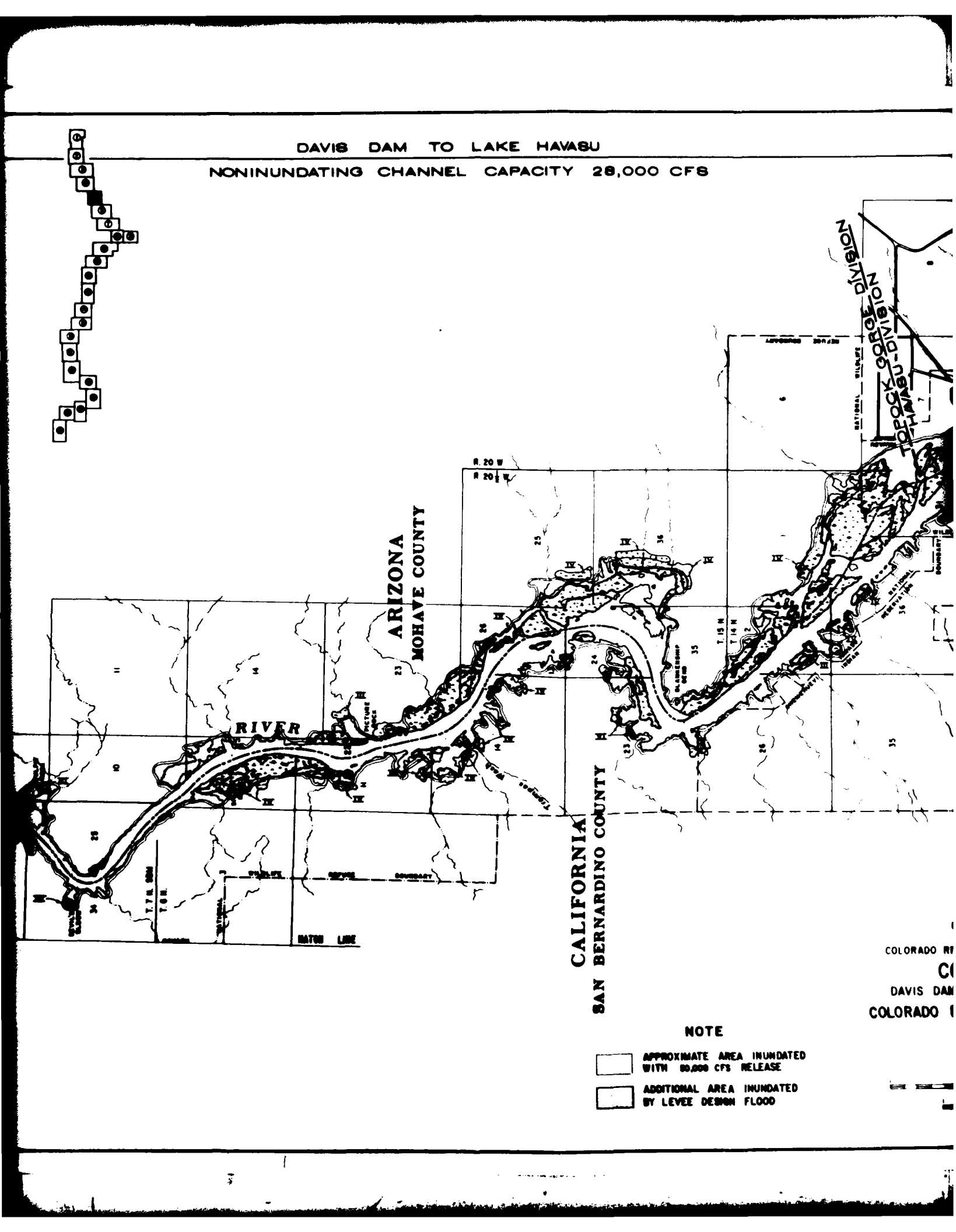
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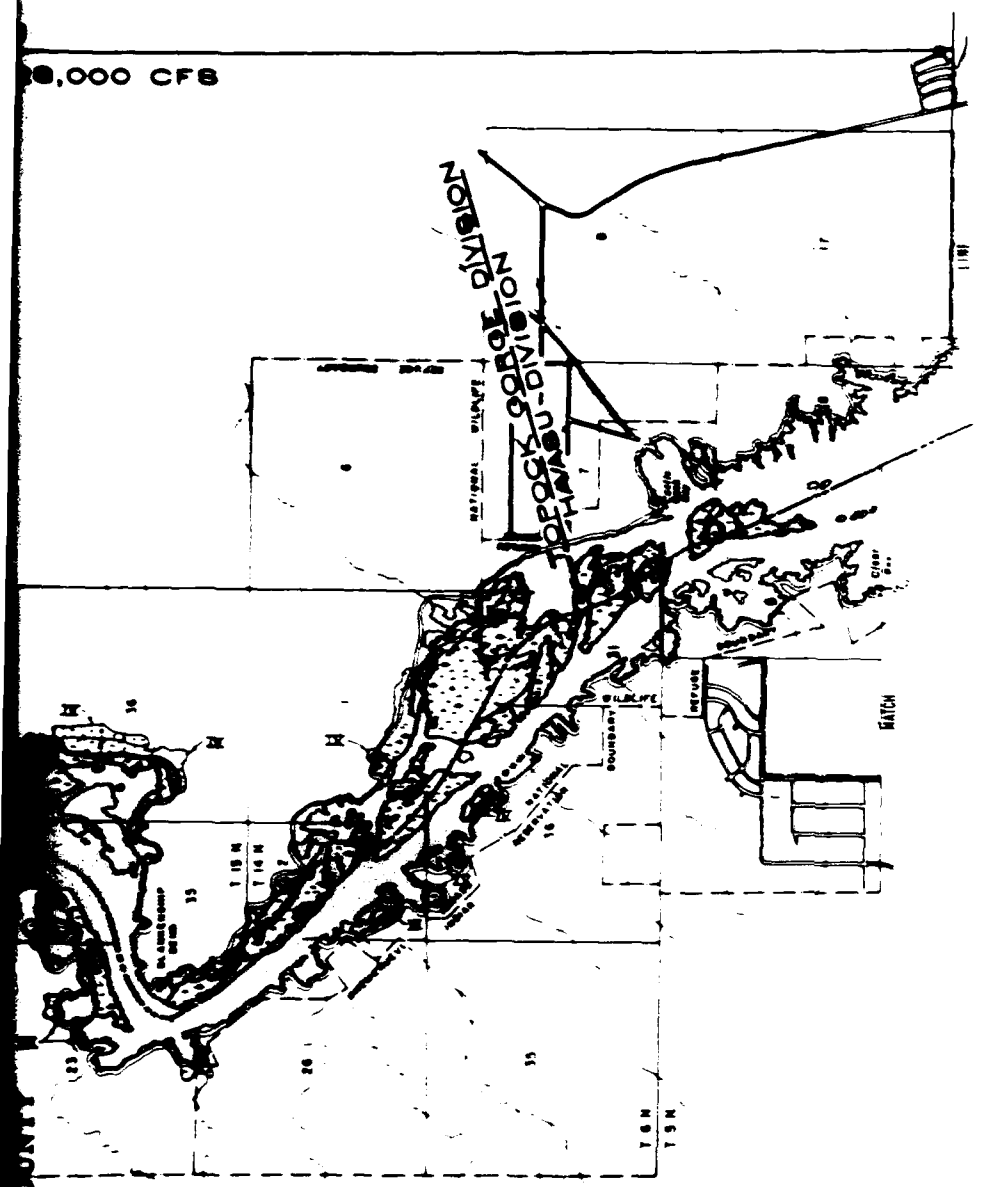
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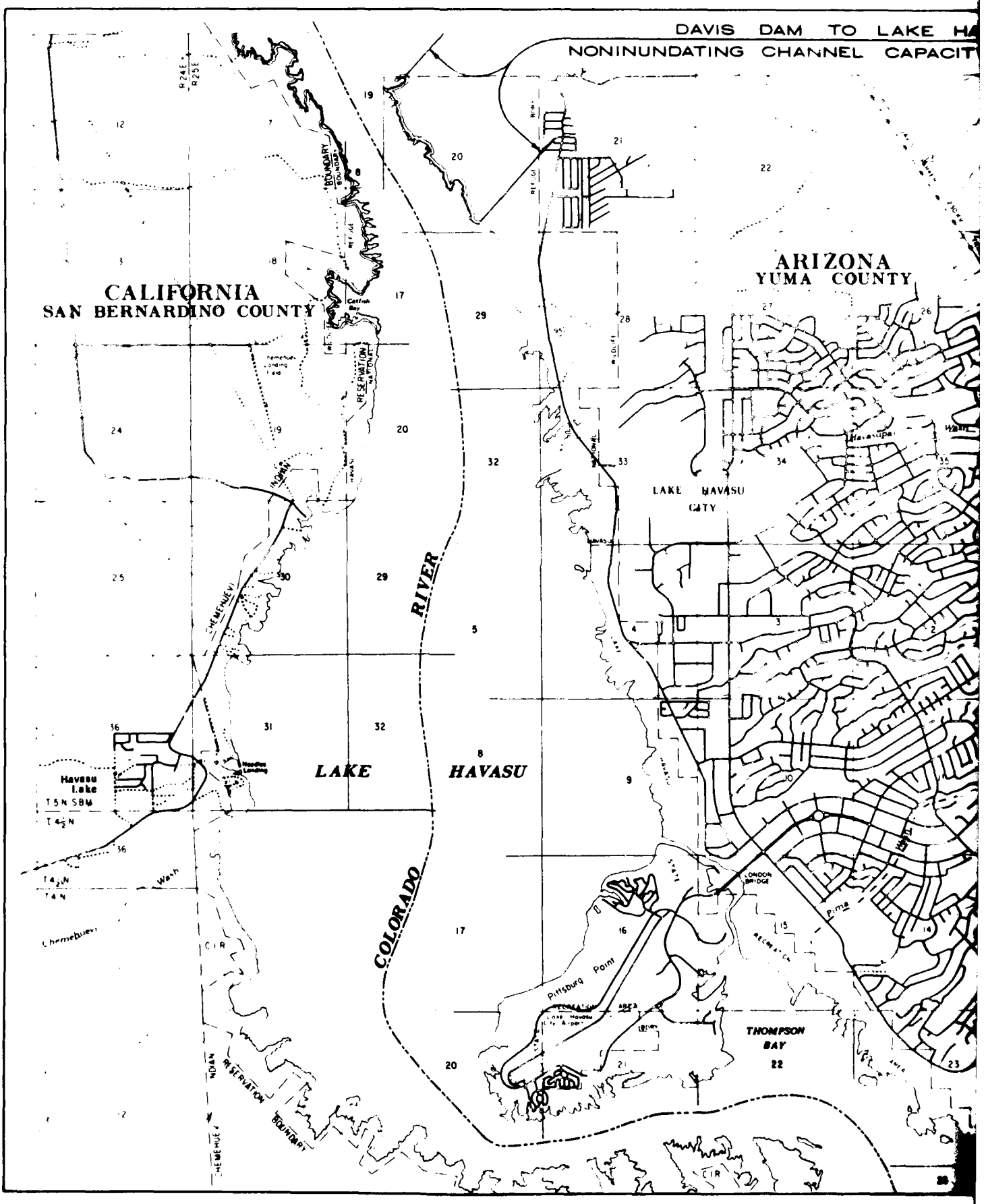
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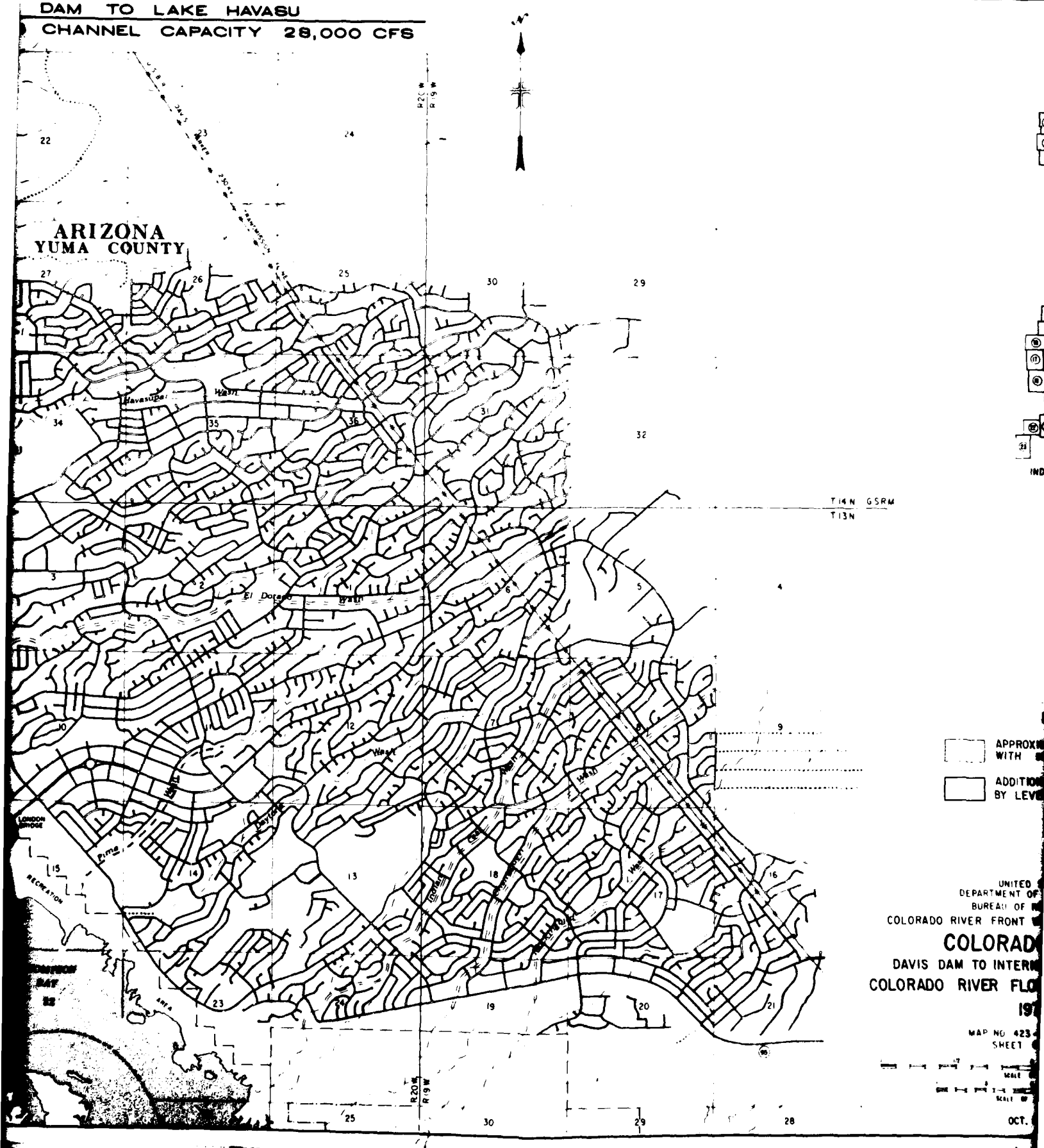
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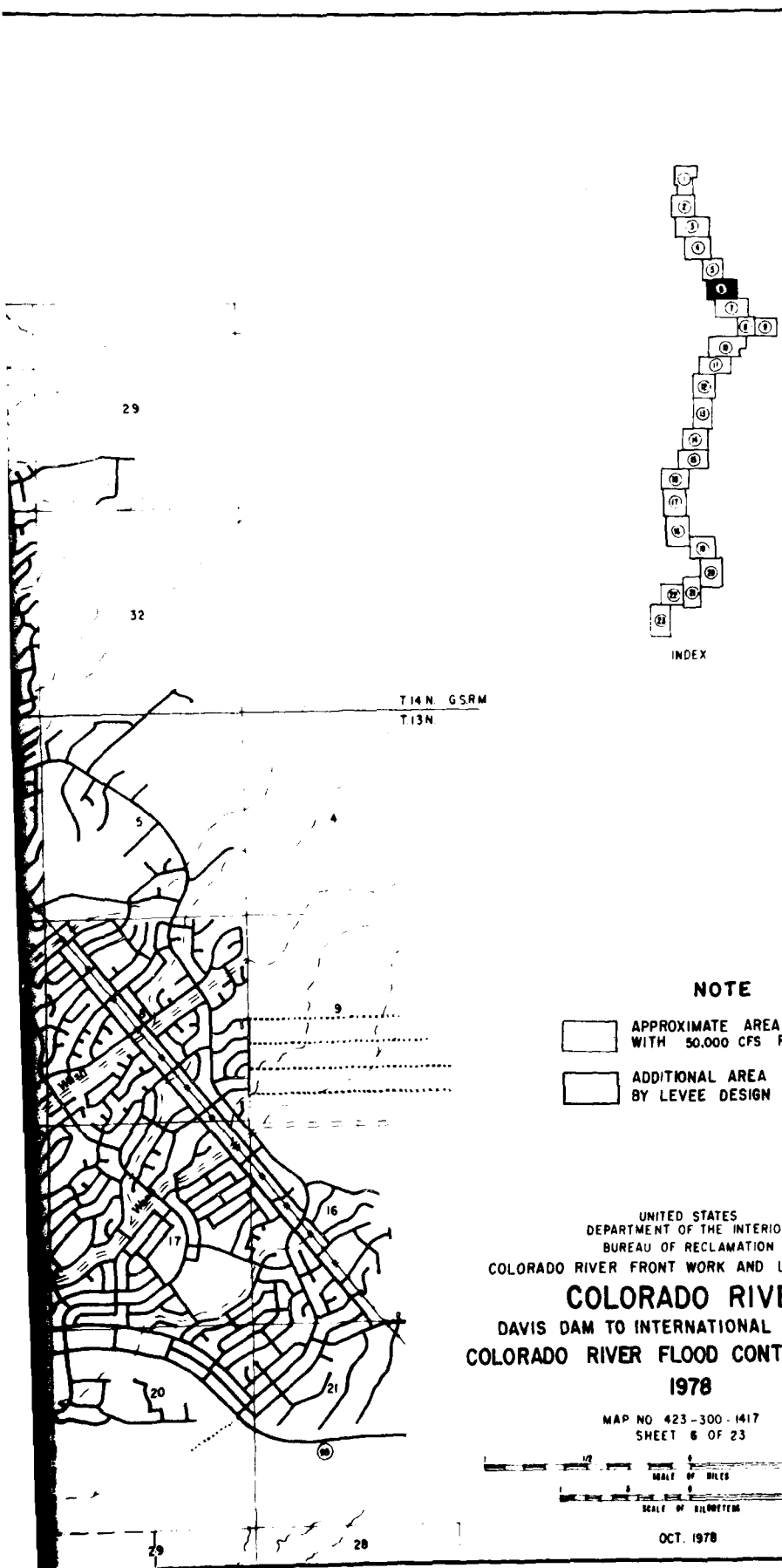
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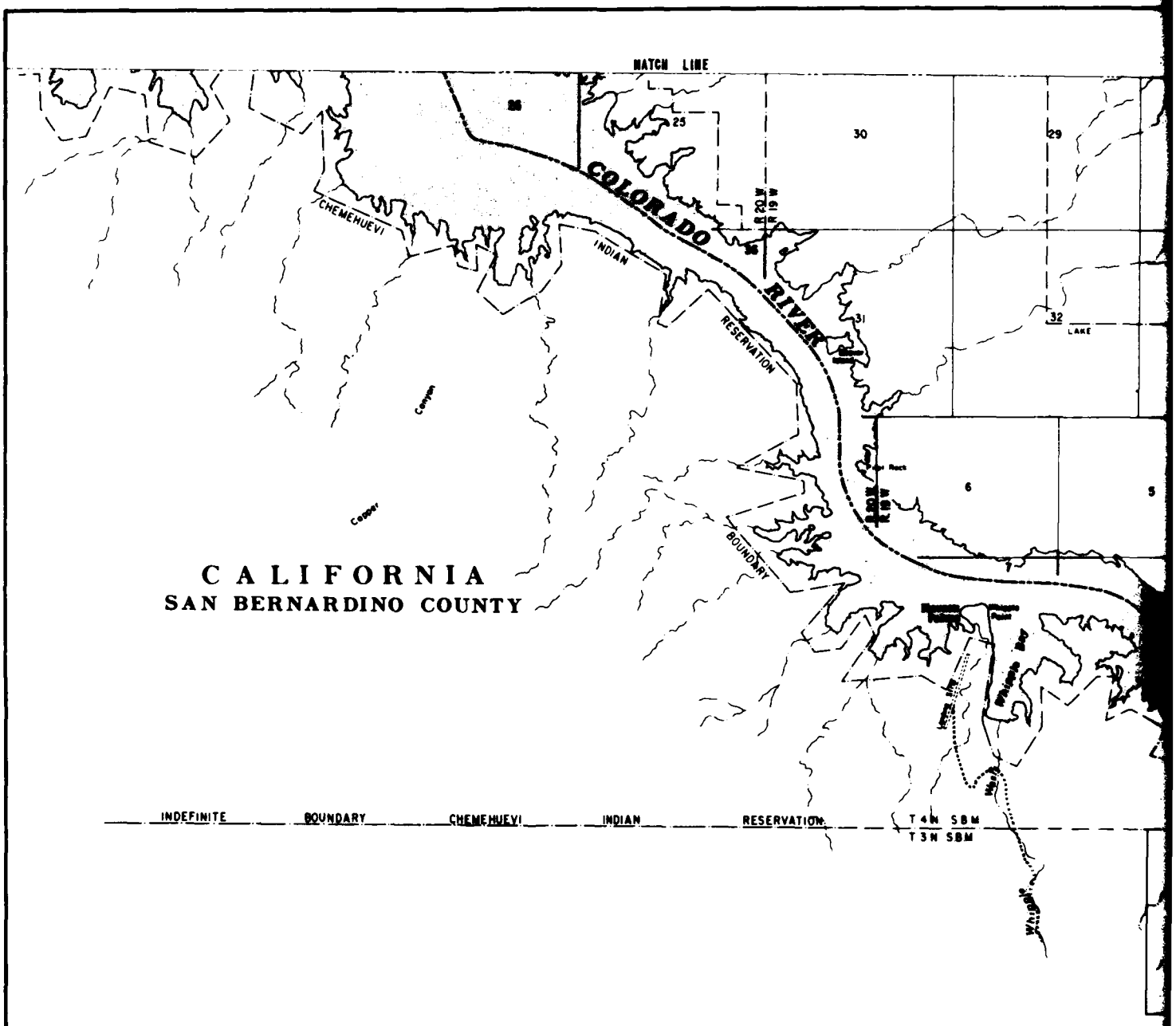
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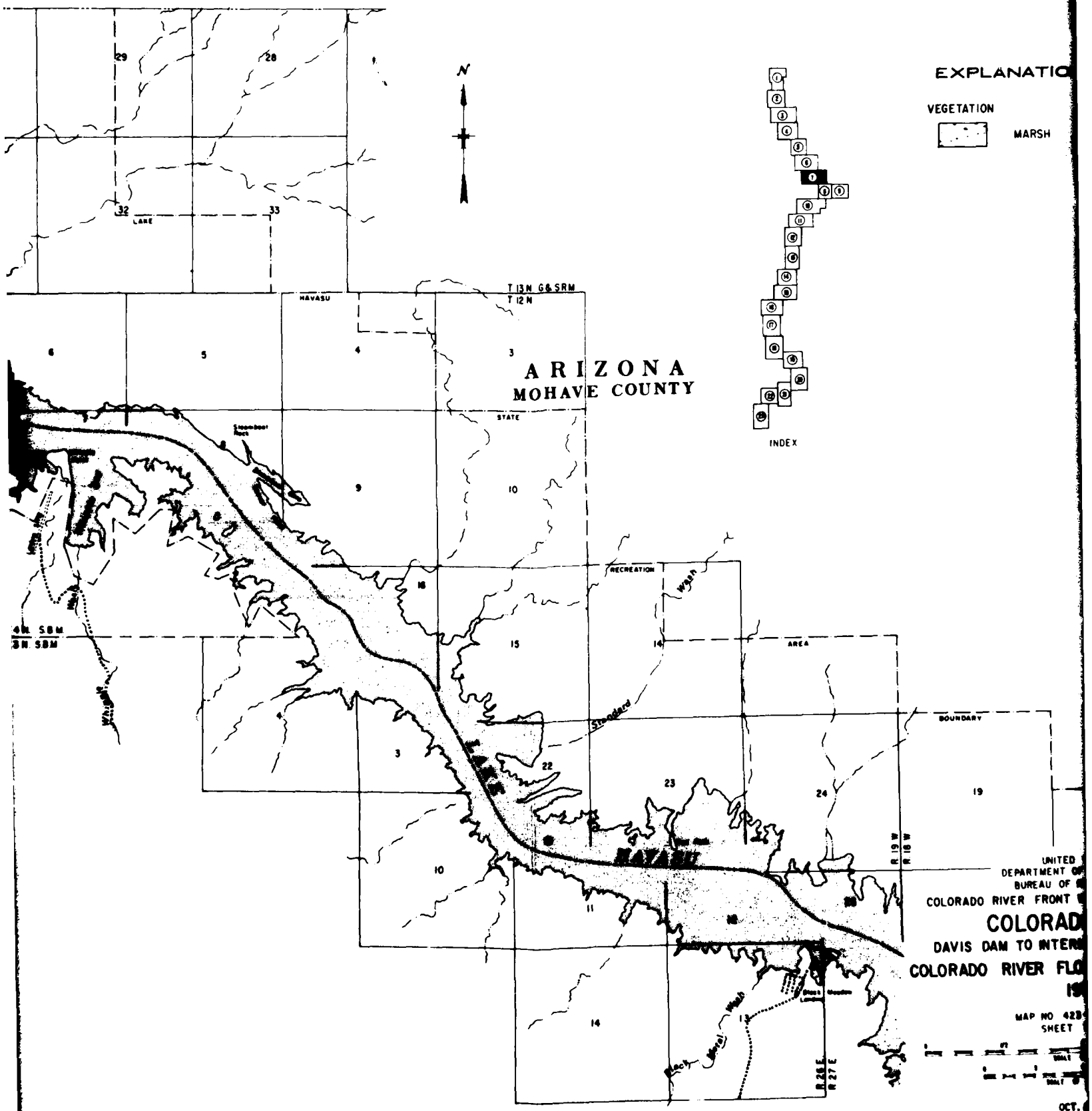
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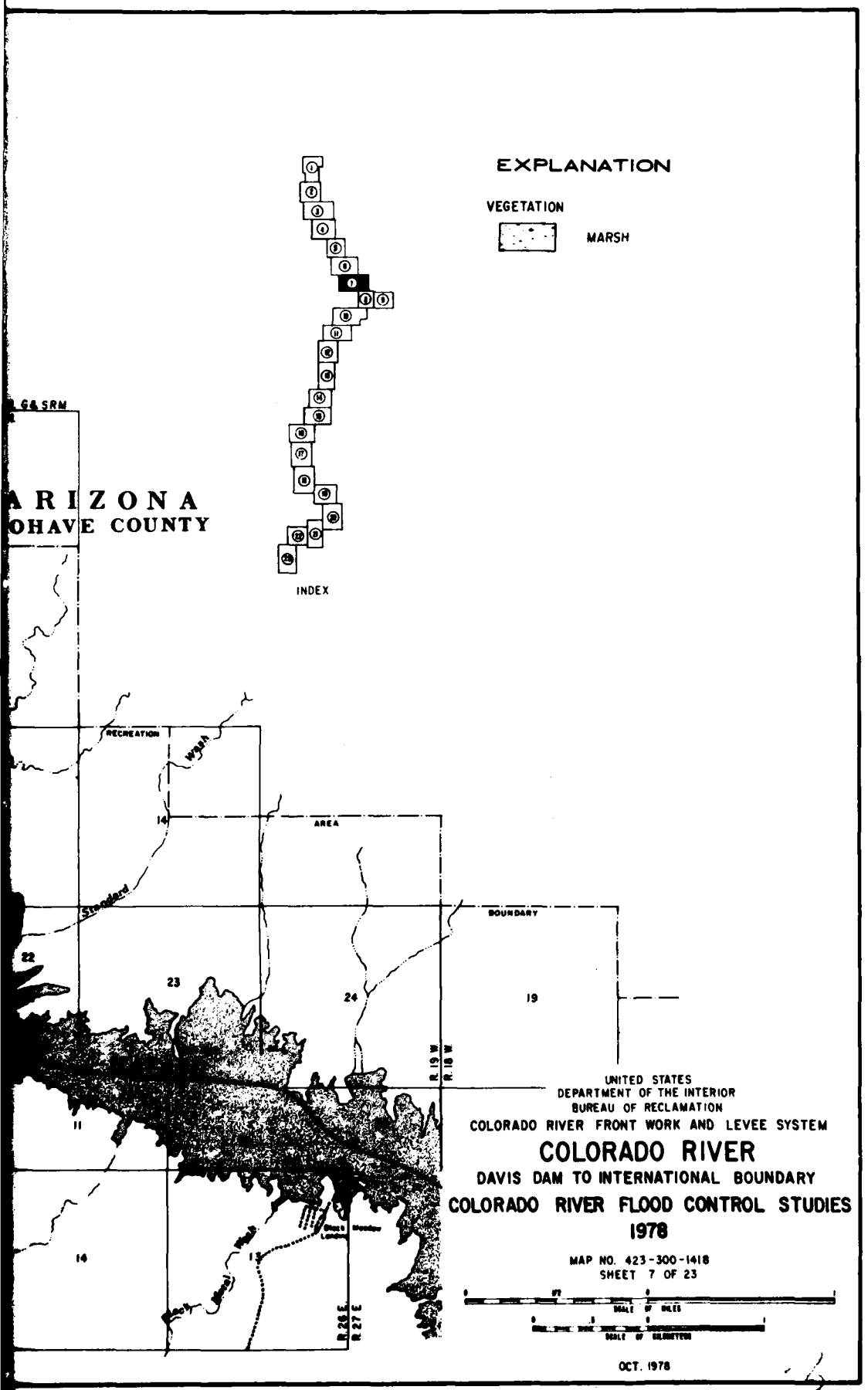
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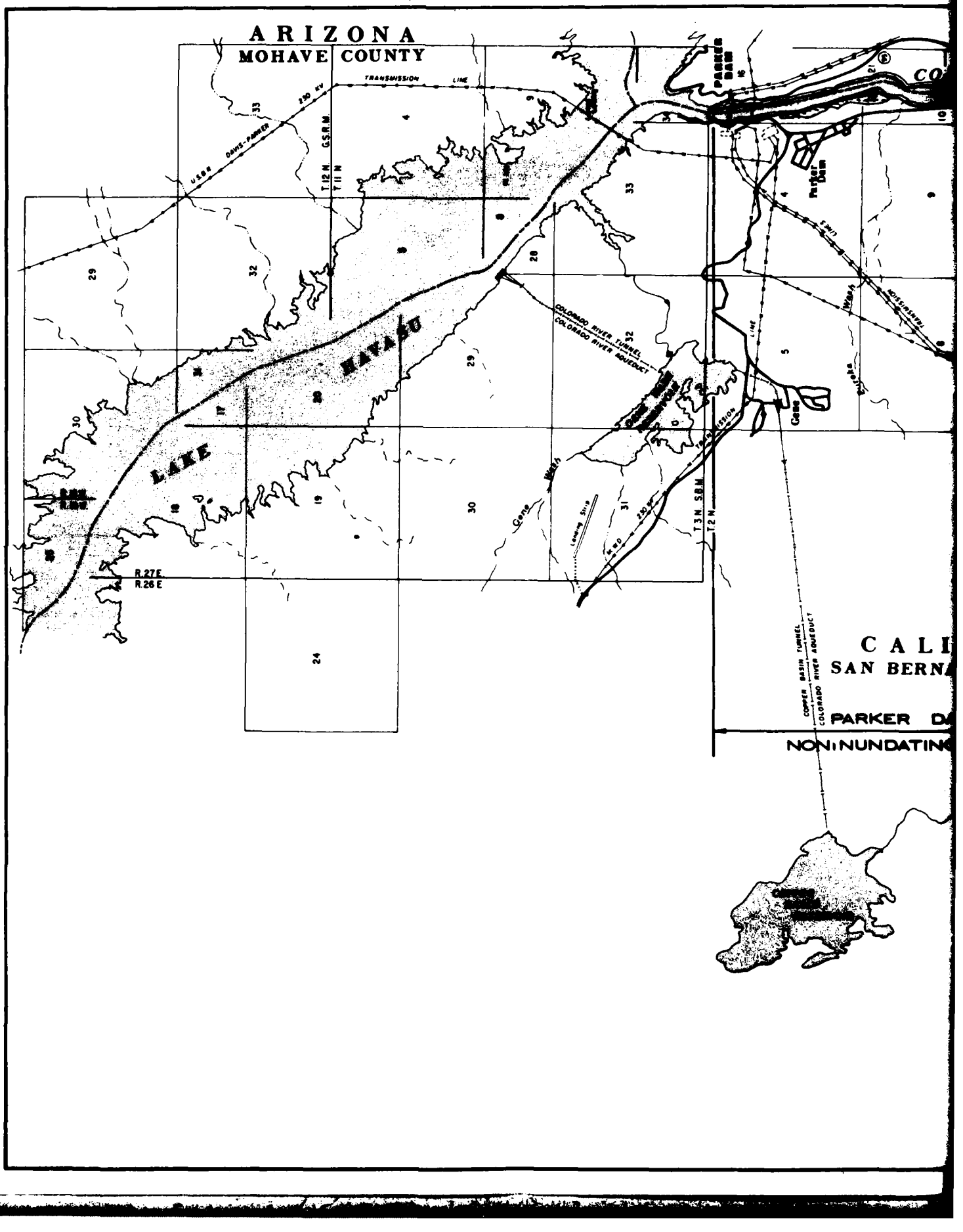
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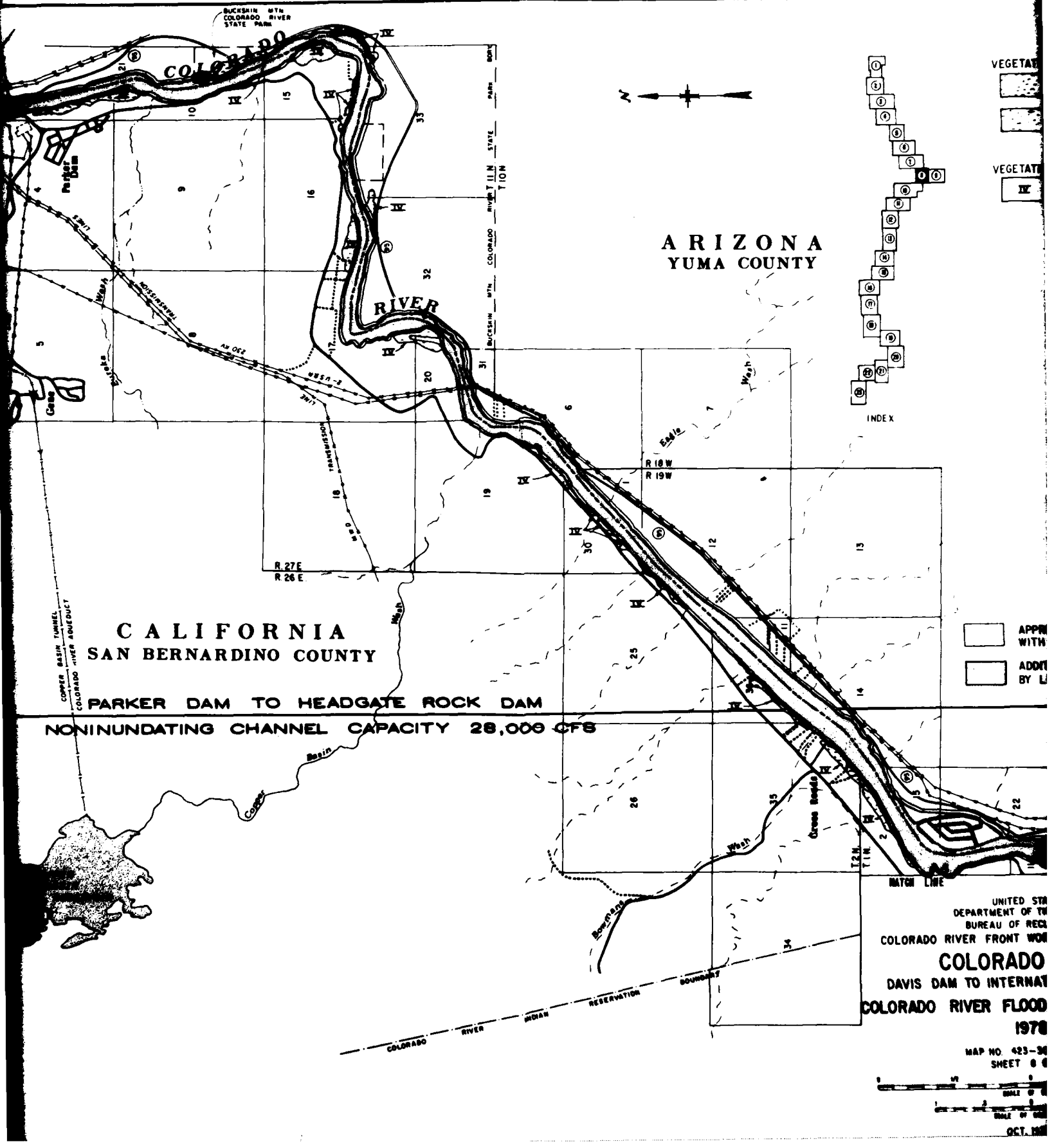
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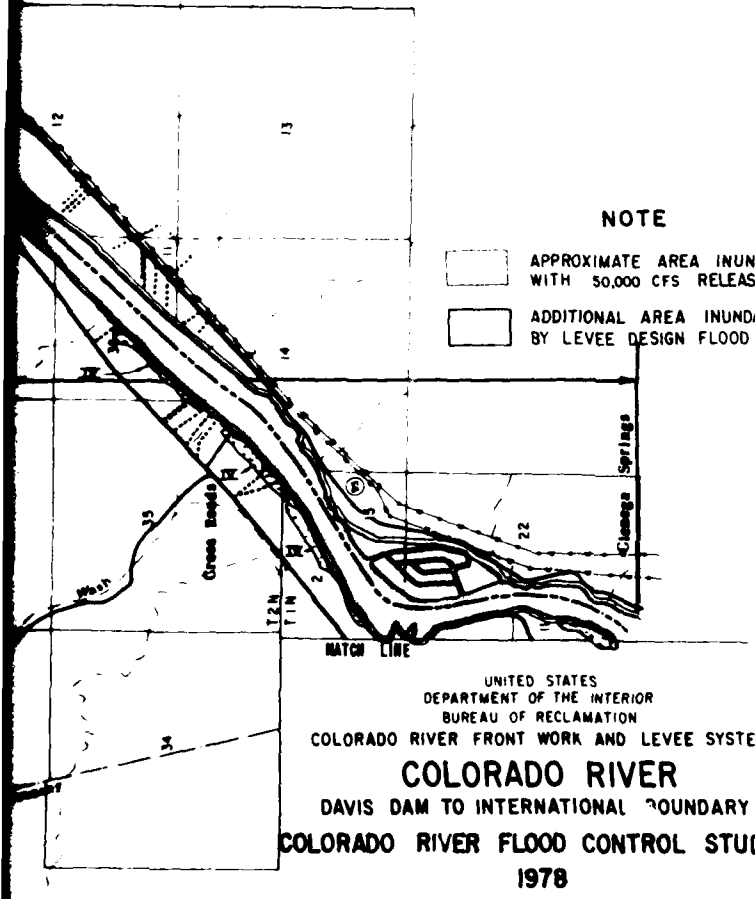
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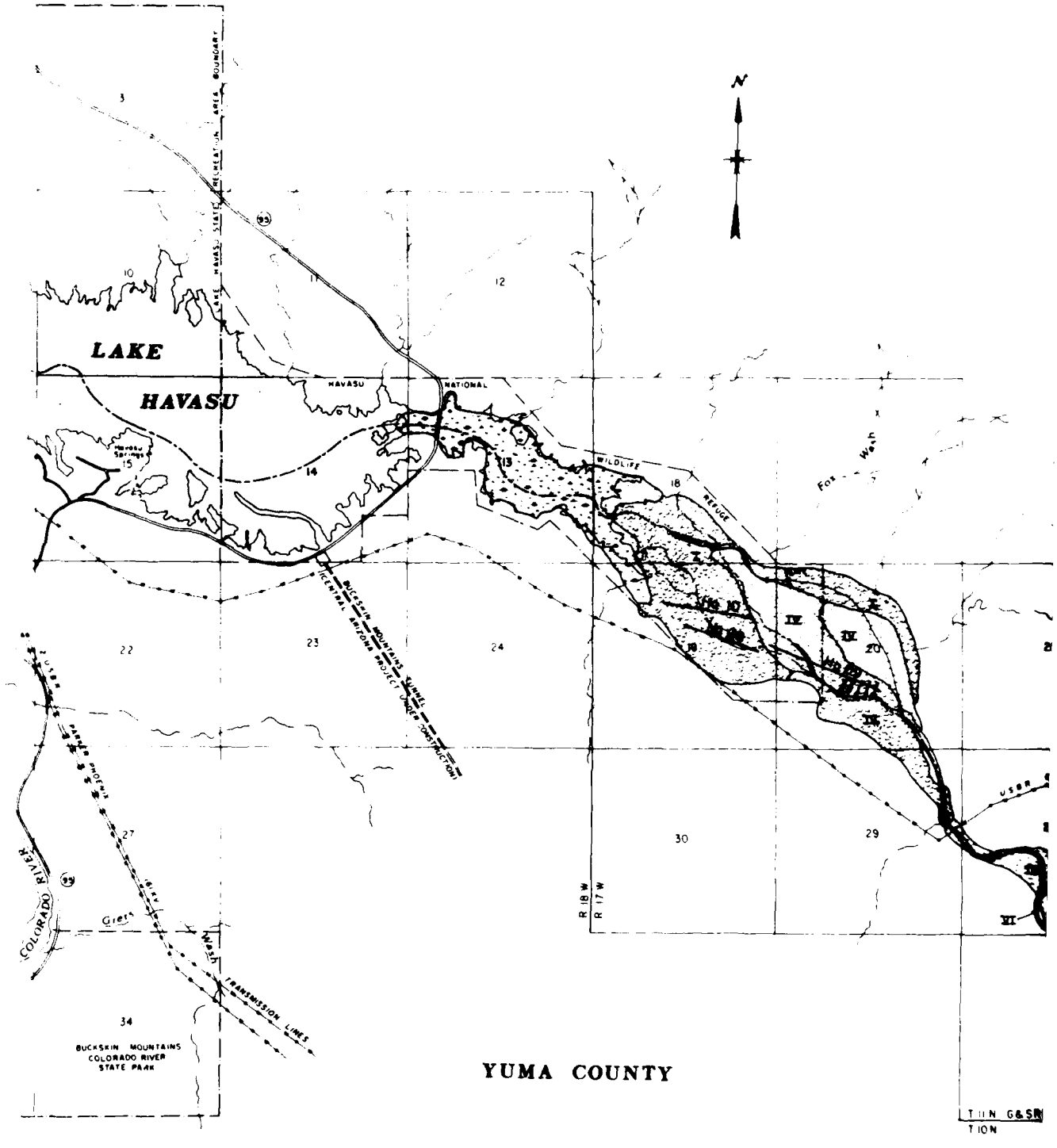
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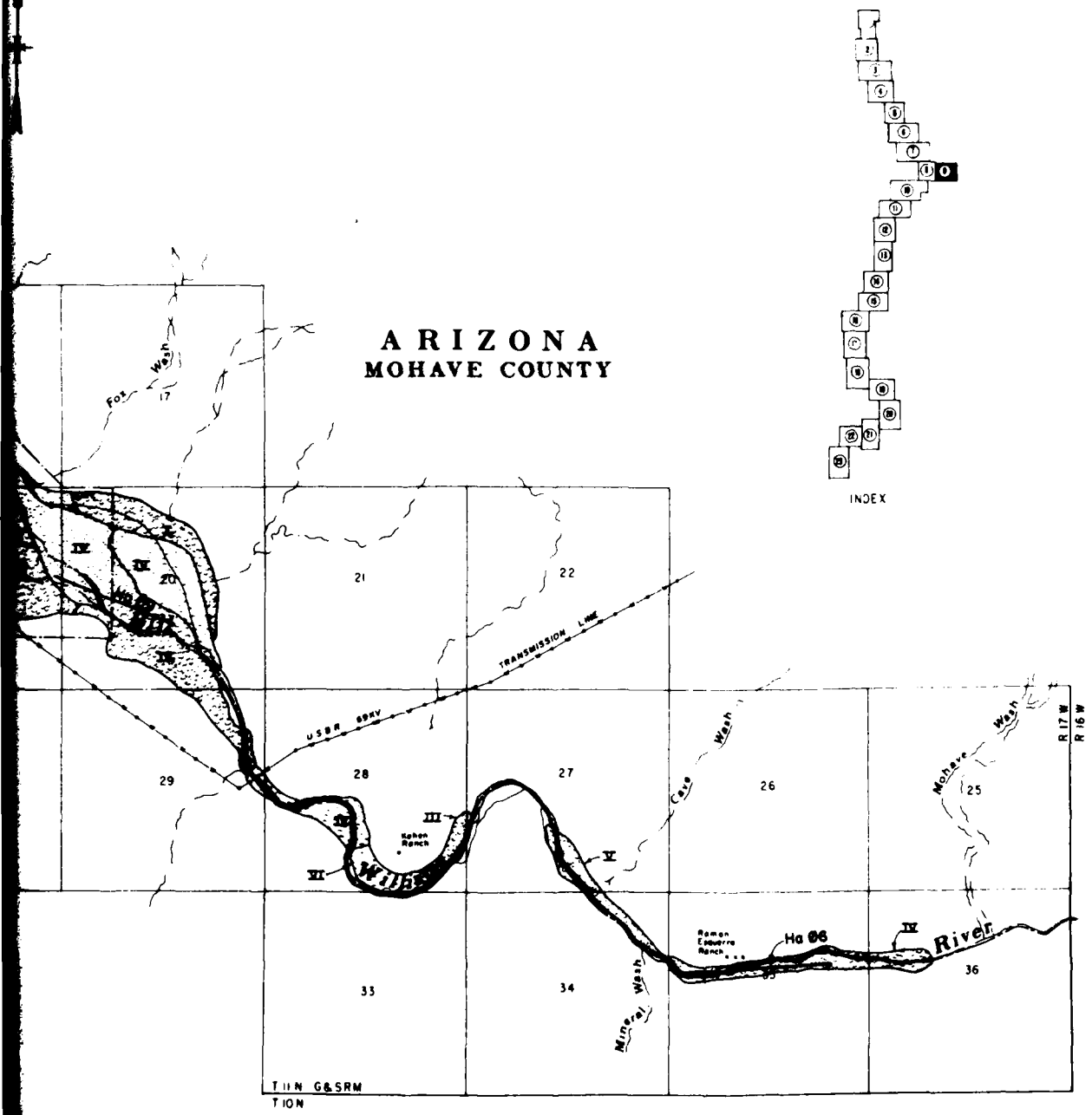
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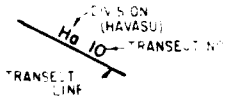
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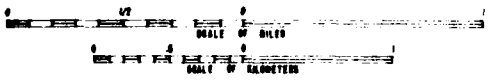
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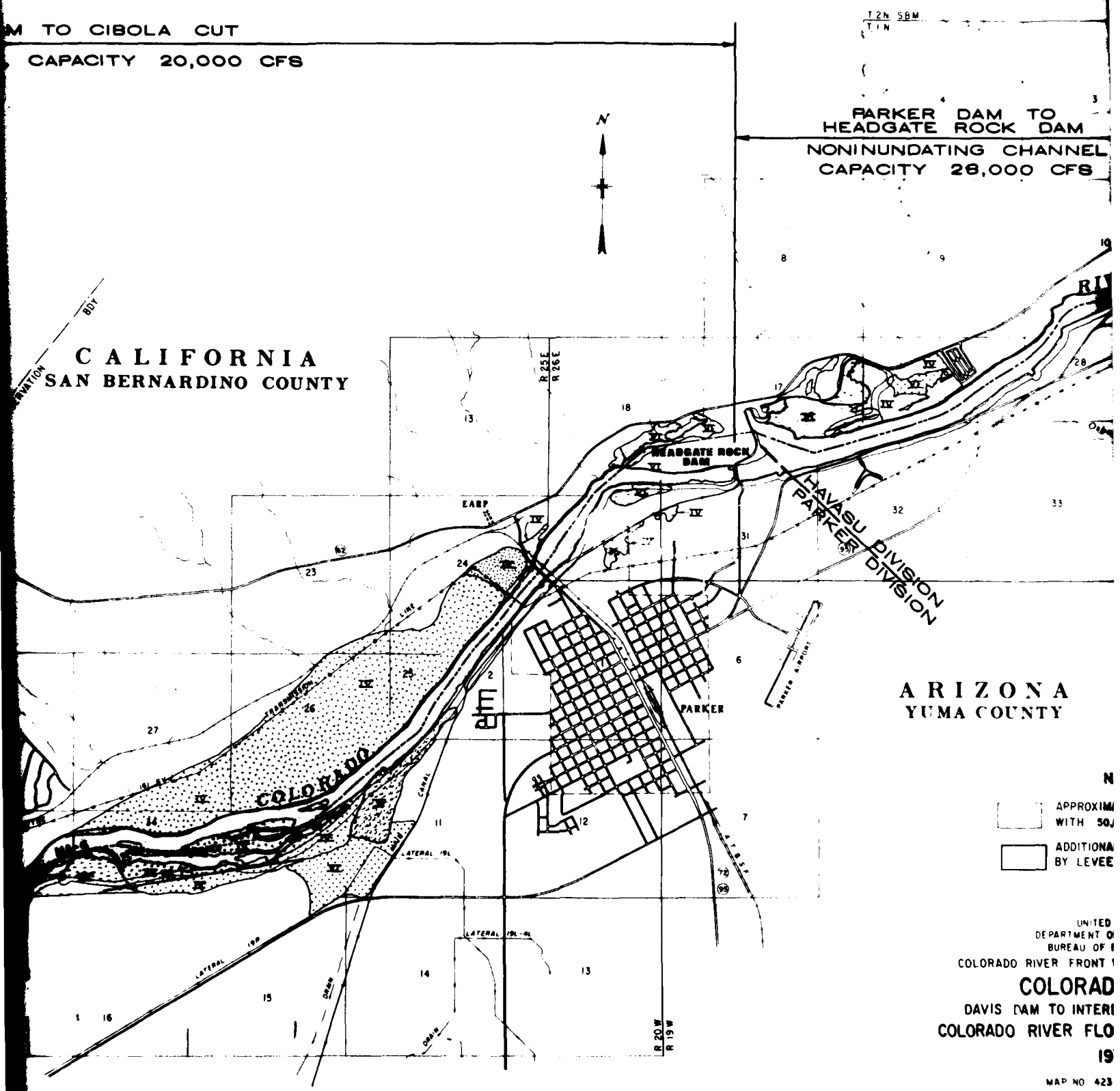


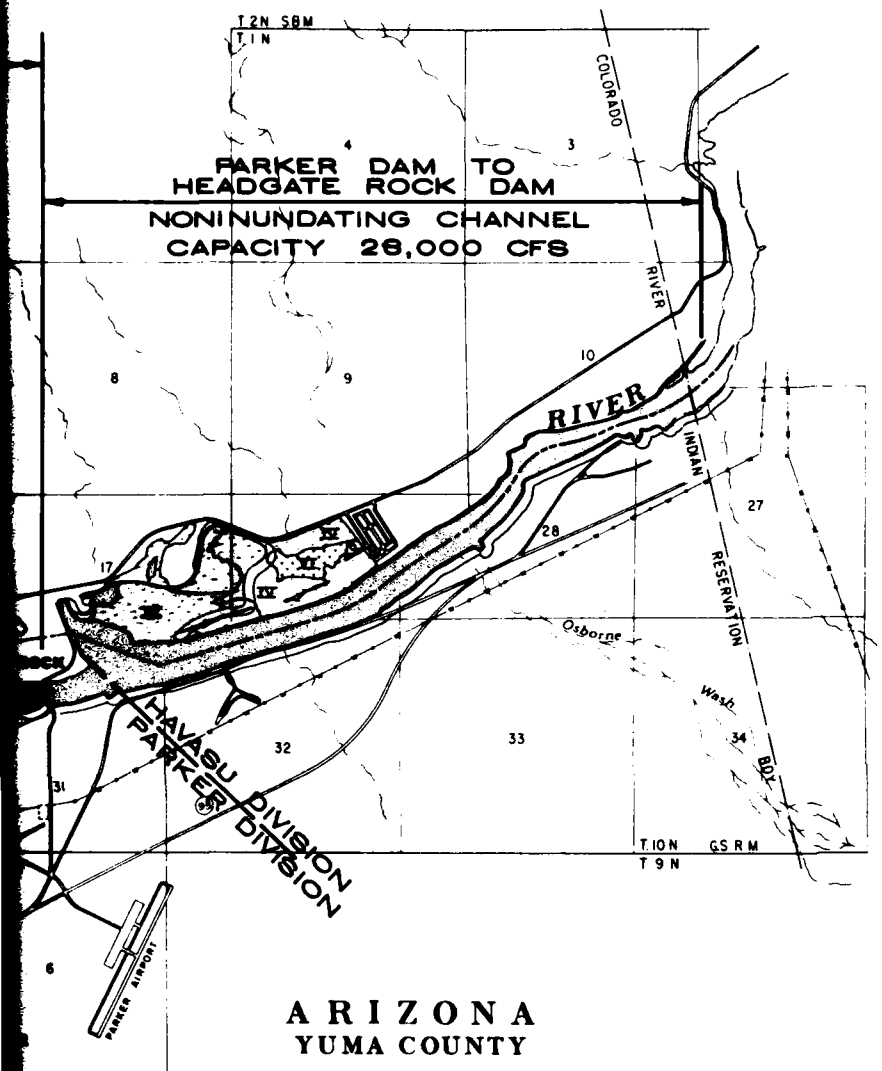
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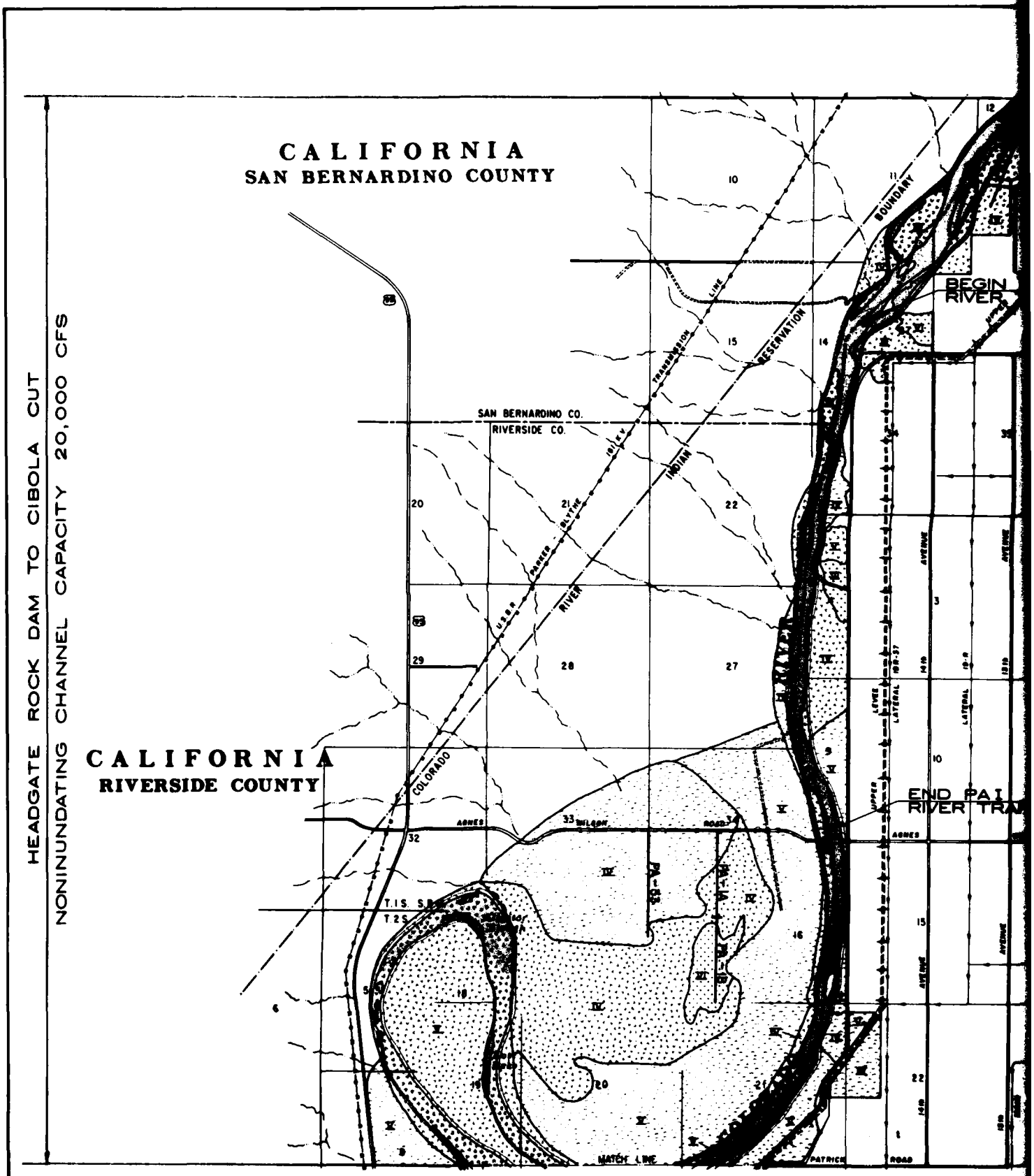
DAVIS DAM TO INTERNATIONAL BOUNDARY

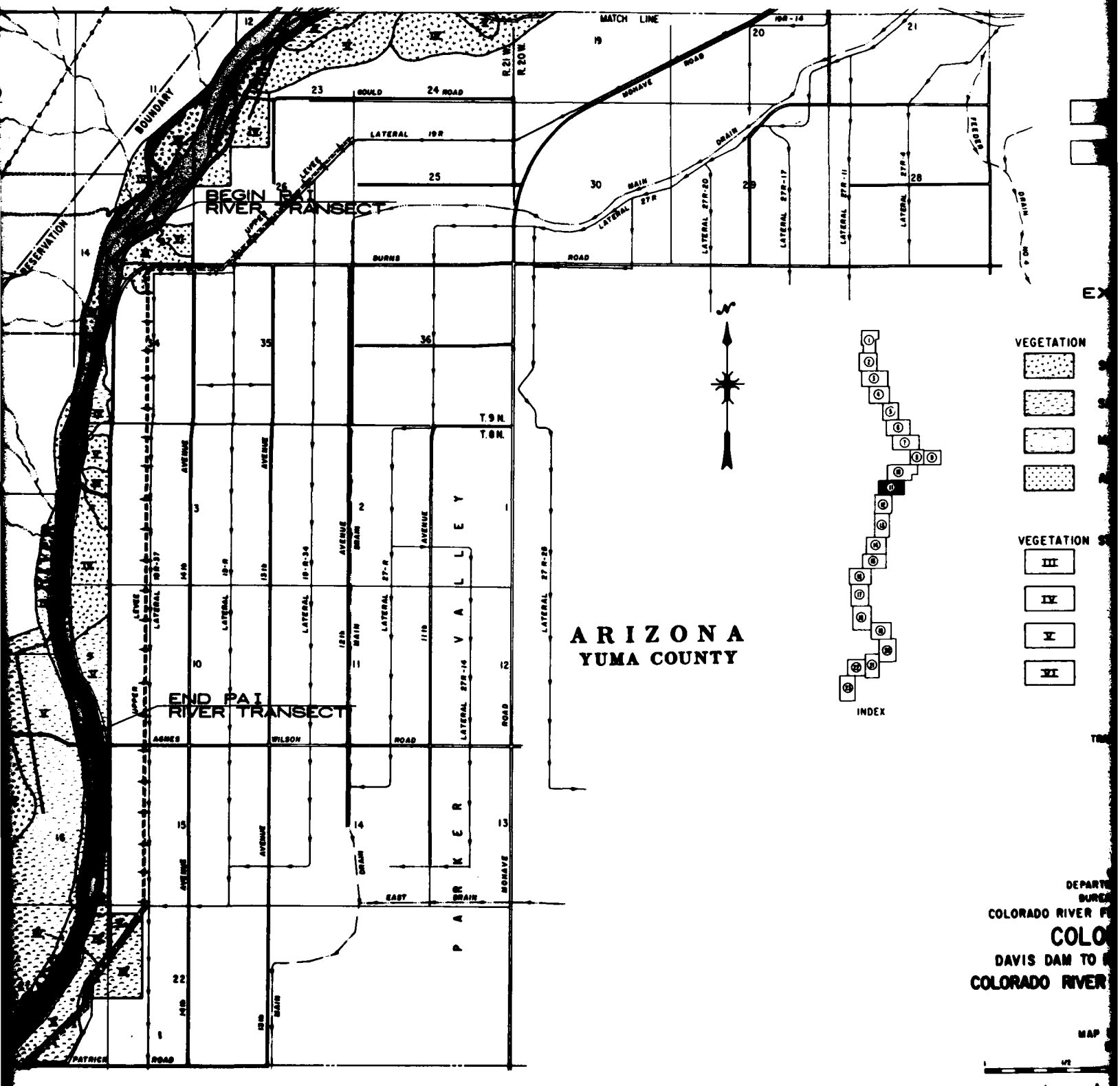
COLORADO RIVER FLOOD CONTROL STUDIES

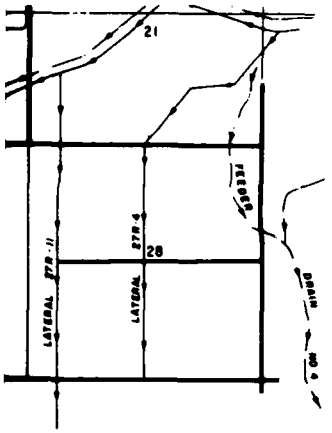
1978

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HEADGATE ROCK DAM TO CIBOLA CUT
NONINUNDATING CHANNEL CAPACITY 20,000 CFS
CALIFORNIA
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CALIFORNIA
RIVERSIDE COUNTY
SAN BERNARDINO CO.
RIVERSIDE CO.
COLORADO
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RESERVATION
BOUNDARY
TRANSMISSION
LINE
BLYTHE
PARKER
AGNES
WILSON
ROAD
MATCH LINE
PATRICK
ROAD
BEGIN
RIVER
END PA
RIVER TRA


MATCH LINE
BEGIN PAI RIVER TRANSECT
END PAI RIVER TRANSECT
BOULDER
BOUNDARY
RESERVATION
GOULD ROAD
BURNS ROAD
MOHAVE ROAD
MAIN DRAIN
LATERAL 19R
LATERAL 27R
LATERAL 27R-20
LATERAL 27R-17
LATERAL 27R-11
LATERAL 27R-4
LATERAL 27R-28
LATERAL 27R-14
LATERAL 19-R-37
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AVENUE
DRAIN
WILSON ROAD
AGNES ROAD
PATRICK ROAD
EAST MOHAVE MAIN DRAIN
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T. 8 N.
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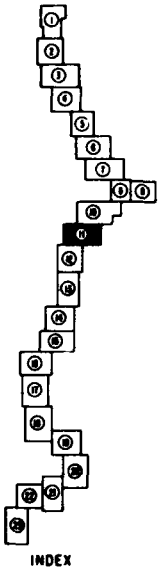


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APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE

ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

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TRANSECT LINE — P-33 — TRANSECT NO.

UNITED STATES
DEPARTMENT OF THE INTERIOR
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DAVIS DAM TO INTERNATIONAL BOUNDARY

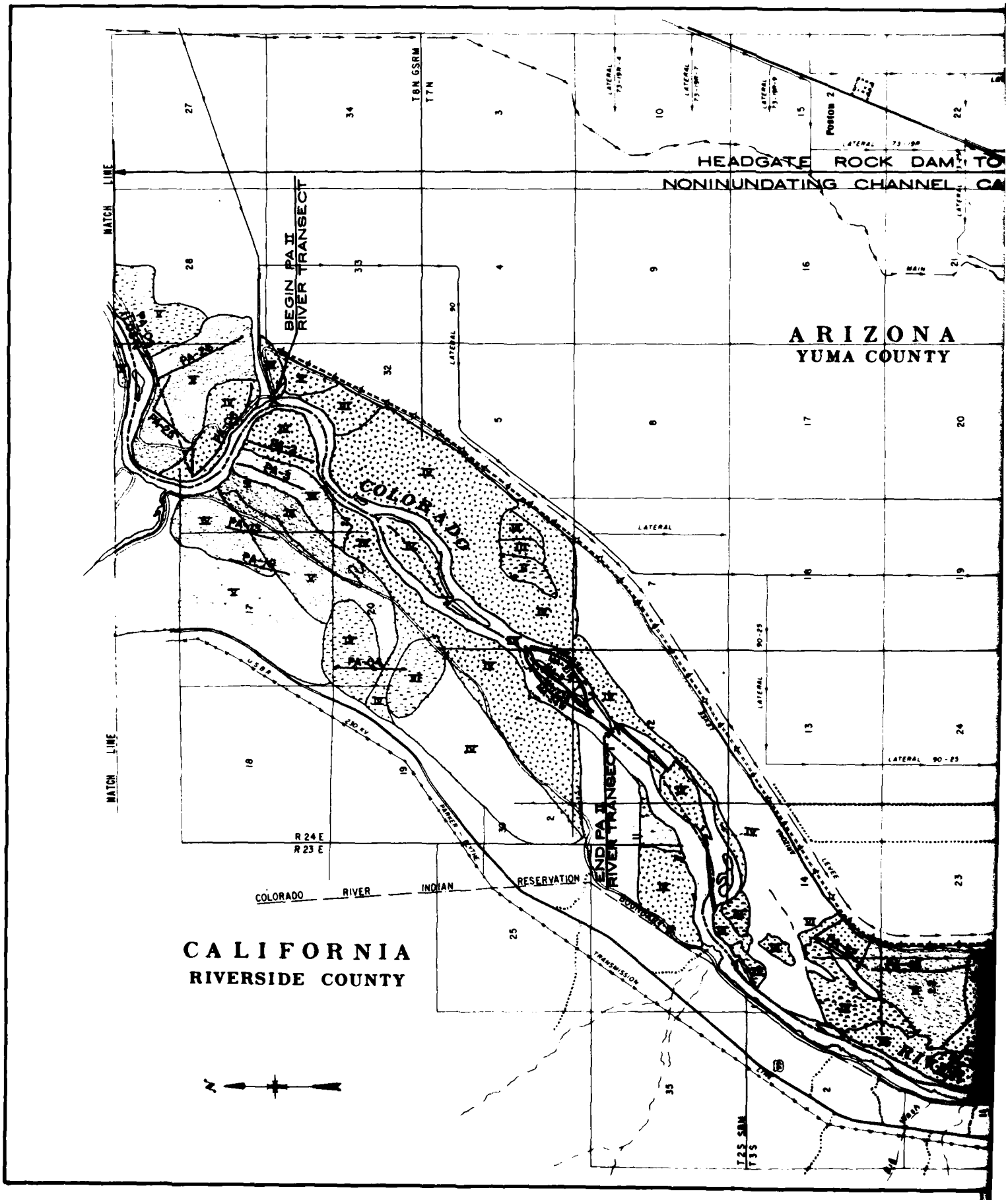
COLORADO RIVER FLOOD CONTROL STUDIES

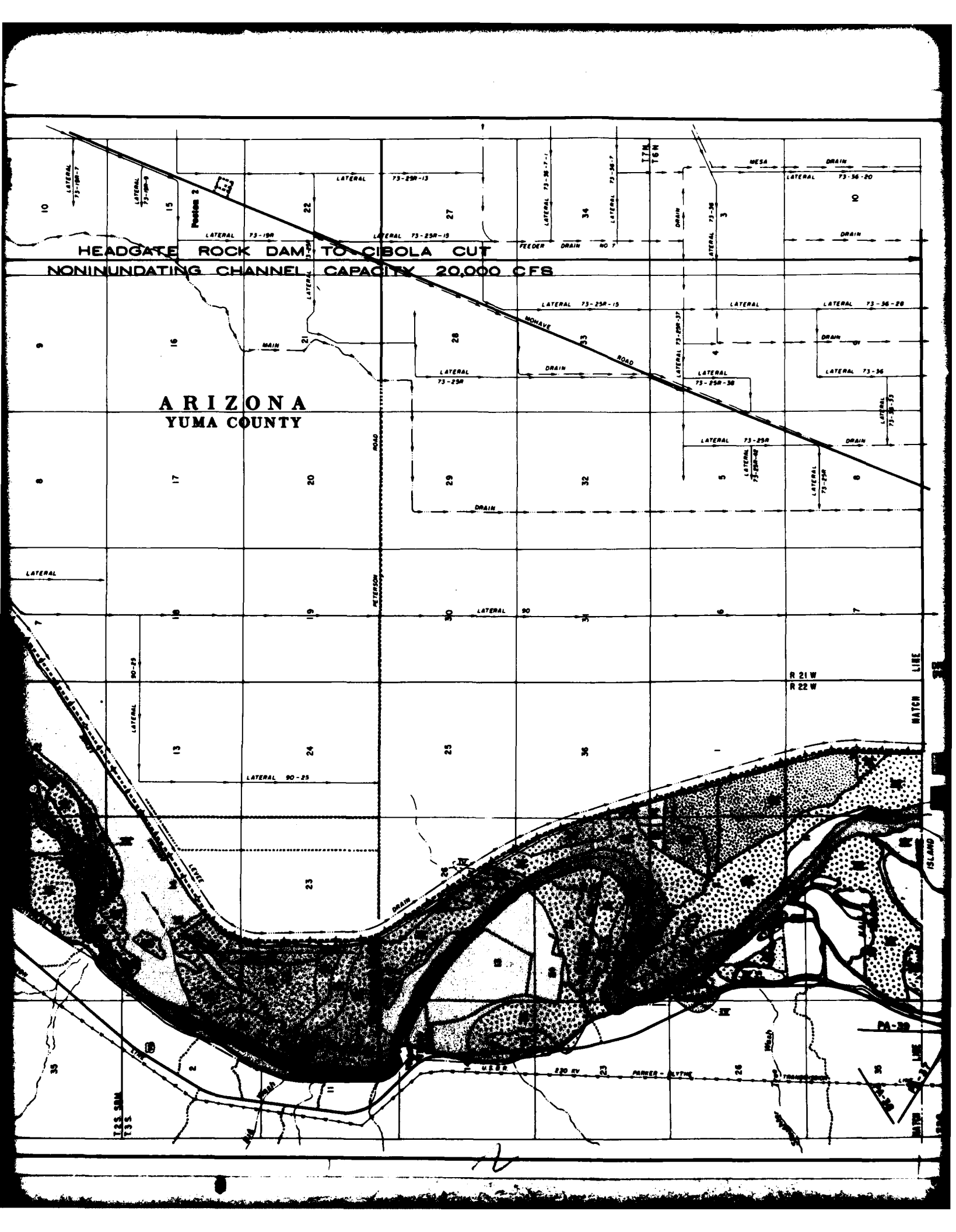
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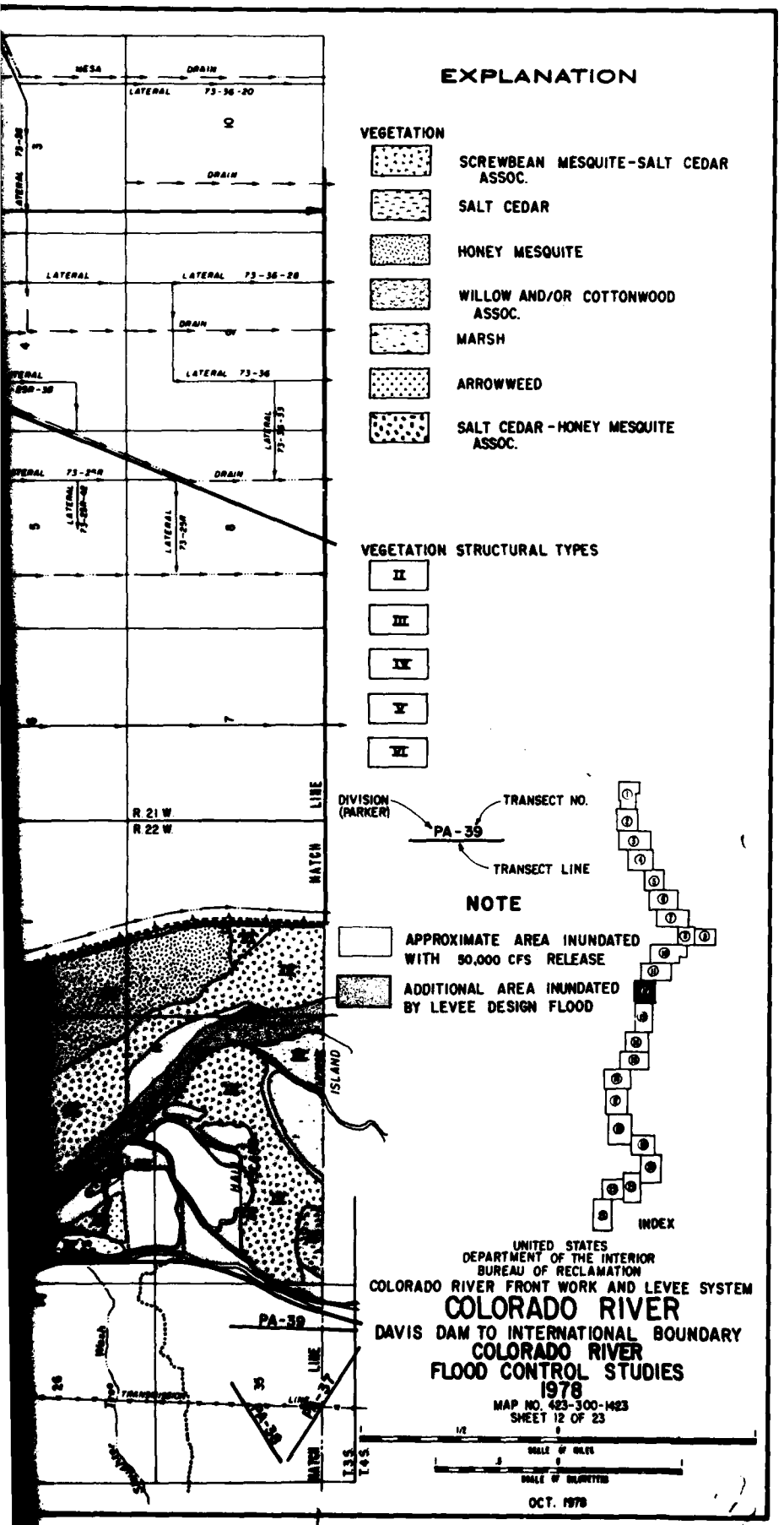
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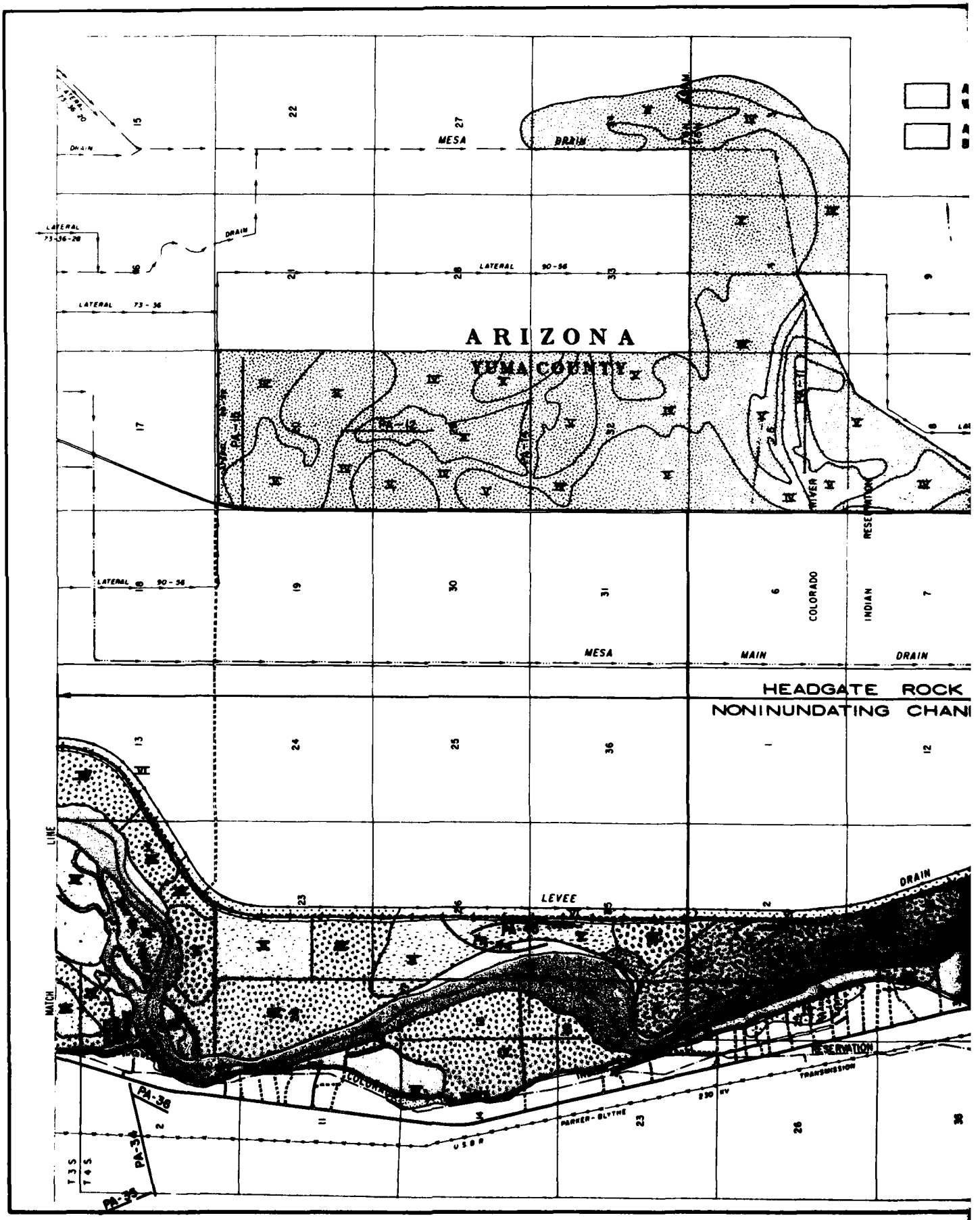


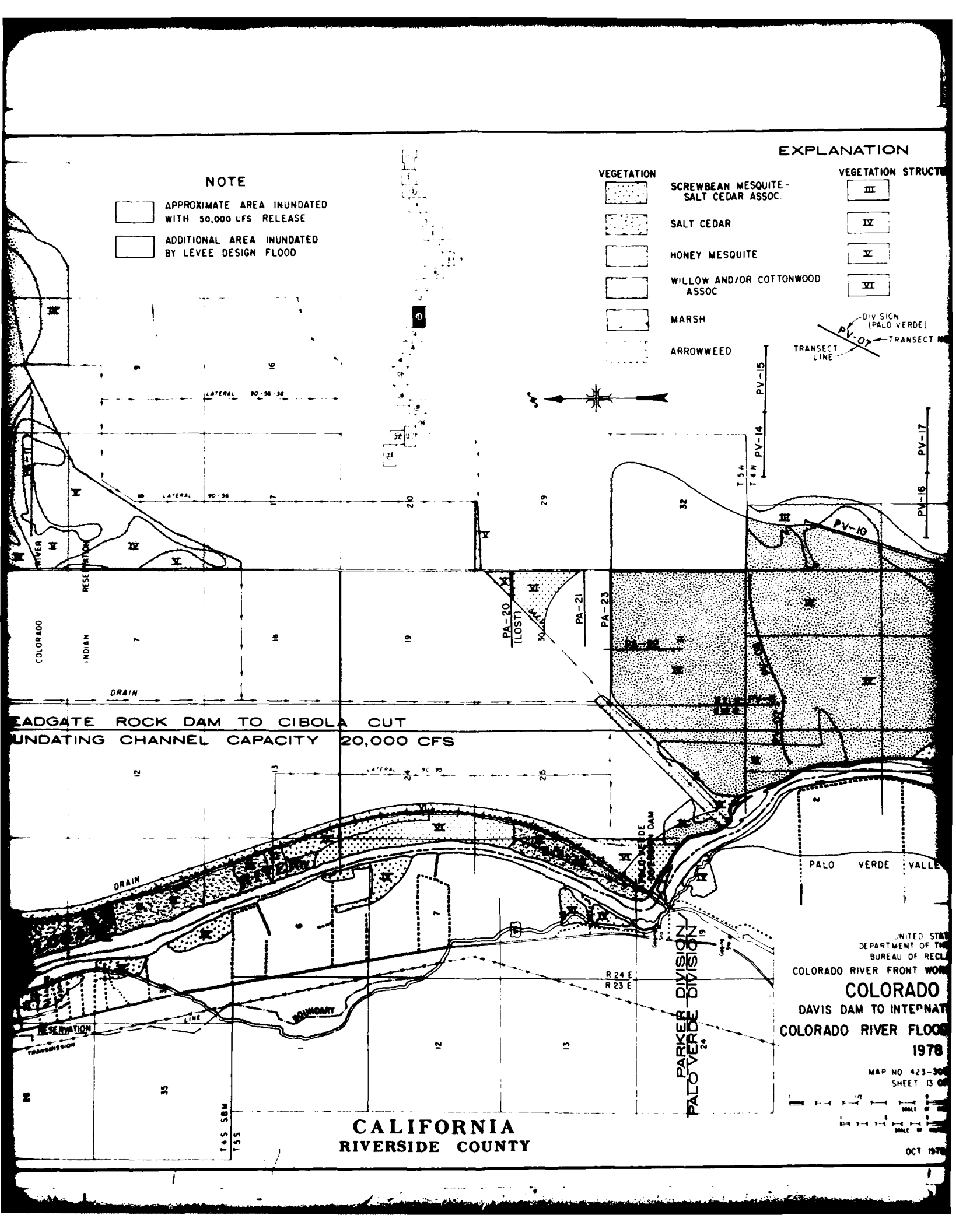
OCT. 1978


HEADGATE ROCK DAM TO
NONINUNDATING CHANNEL CA
ARIZONA
YUMA COUNTY
CALIFORNIA
RIVERSIDE COUNTY
COLORADO RIVER INDIAN RESERVATION
BEGIN PA II RIVER TRANSECT
END PA II RIVER TRANSECT
MATCH LINE
MATCH LINE
T8N GSRM
T7N
R 24 E
R 23 E
T 25 SBM
T 3 S
COLORADO
LATERAL
MAIN
LEVEE
TRANSMISSION
BOUNDARY
N


HEADGATE ROCK DAM TO CIBOLA CUT
NONINUNDATING CHANNEL CAPACITY 20,000 CFS
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YUMA COUNTY
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LATERAL 73-25R-13
LATERAL 73-25R-15
LATERAL 73-25R-37
LATERAL 73-25R-38
LATERAL 73-25R-41
LATERAL 73-25R
LATERAL 73-36-28
LATERAL 73-36
LATERAL 73-35-33
LATERAL 73-25R-9
LATERAL 73-19R-7
LATERAL 73-19R-9
LATERAL 73-19R
LATERAL 73-25R
LATERAL 90
LATERAL 90-25
FEEDER DRAIN NO 7
MAIN
DRAIN
MOHAVE ROAD
PETERSON ROAD
LEVEE
R 21 W
R 22 W
MATCH LINE
ISLAND
T 11 N
T 10 N
T 10 S
T 11 S
U.S.B.R.
220 KV
PARKER - BLYTHE
Wash


MESA
DRAIN
LATERAL 73-36-20
LATERAL 73-36-28
LATERAL 73-36
LATERAL 73-36-35
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R 21 W
R 22 W
MATCH LINE
ISLAND
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MATCH LINE
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DRAIN
LATERAL 73-36-28
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LATERAL 90-56
PA-12
PA-36
PA-34
PA-35
MESA MAIN DRAIN
COLORADO
INDIAN
RESERVATION
HEADGATE ROCK
NONINUNDATING CHANI
LEVEE
DRAIN
MATCH LINE
RESERVATION
TRANSMISSION
230 KV
PARKER-BLYTHE
T3S
T4S

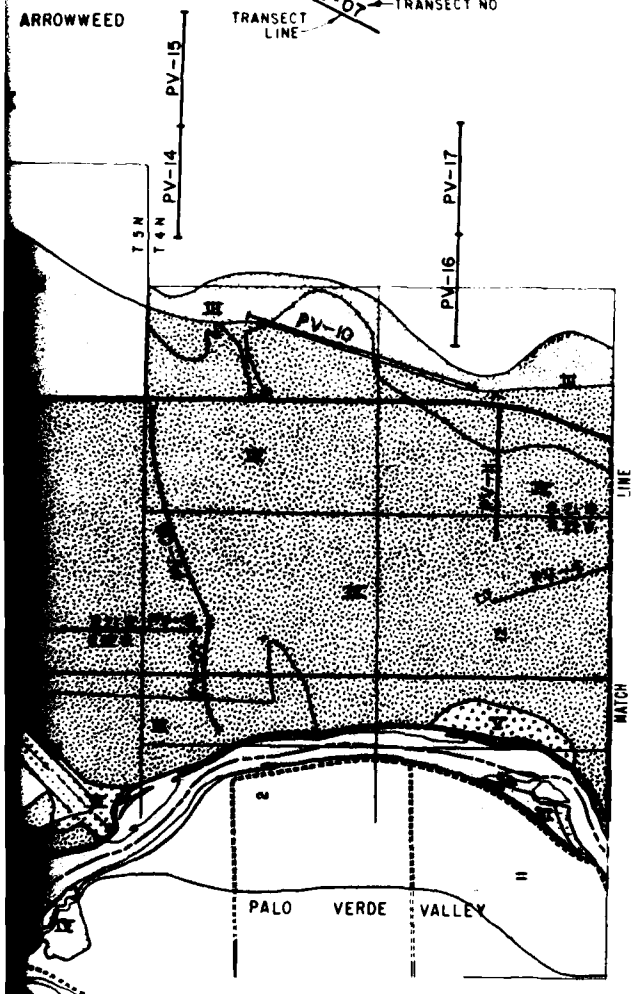

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ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD
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PA-21
PA-23
T 5 N
T 4 N
COLORADO INDIAN RESERVATION
DRAIN
LATERAL
EADGATE ROCK DAM TO CIBOLA CUT
UNDATING CHANNEL CAPACITY 20,000 CFS
PALO VERDE DIVERSION DAM
PALO VERDE VALLE
PARKER DIVISION
PALO VERDE DIVISION
R 24 E
R 23 E
T 4 S
T 5 S
RESERVATION BOUNDARY LINE
TRANSMISSION
UNITED STA
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COLORADO RIVER FRONT WOR
COLORADO
DAVIS DAM TO INTERNAT
COLORADO RIVER FLOOD
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OCT 197
CALIFORNIA
RIVERSIDE COUNTY

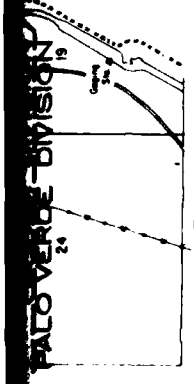
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SALT CEDAR	IV
HONEY MESQUITE	V
WILLOW AND/OR COTTONWOOD ASSOC	VI
MARSH	
ARROWWEED	

DIVISION (PALO VERDE)
PV-07 ← TRANSECT NO
TRANSECT LINE





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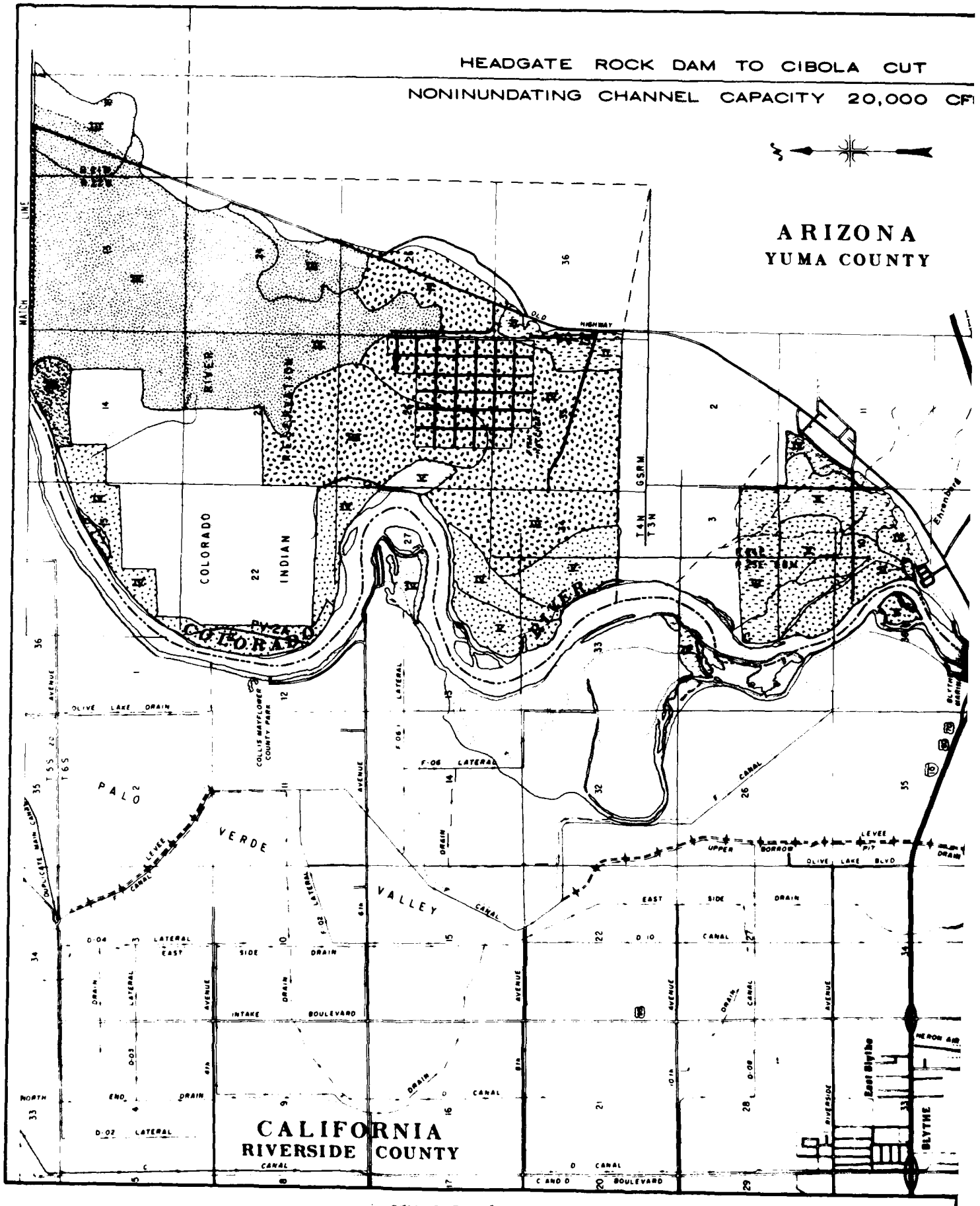
1978

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SCALE OF MILES

SCALE OF KILOMETERS

OCT. 1978

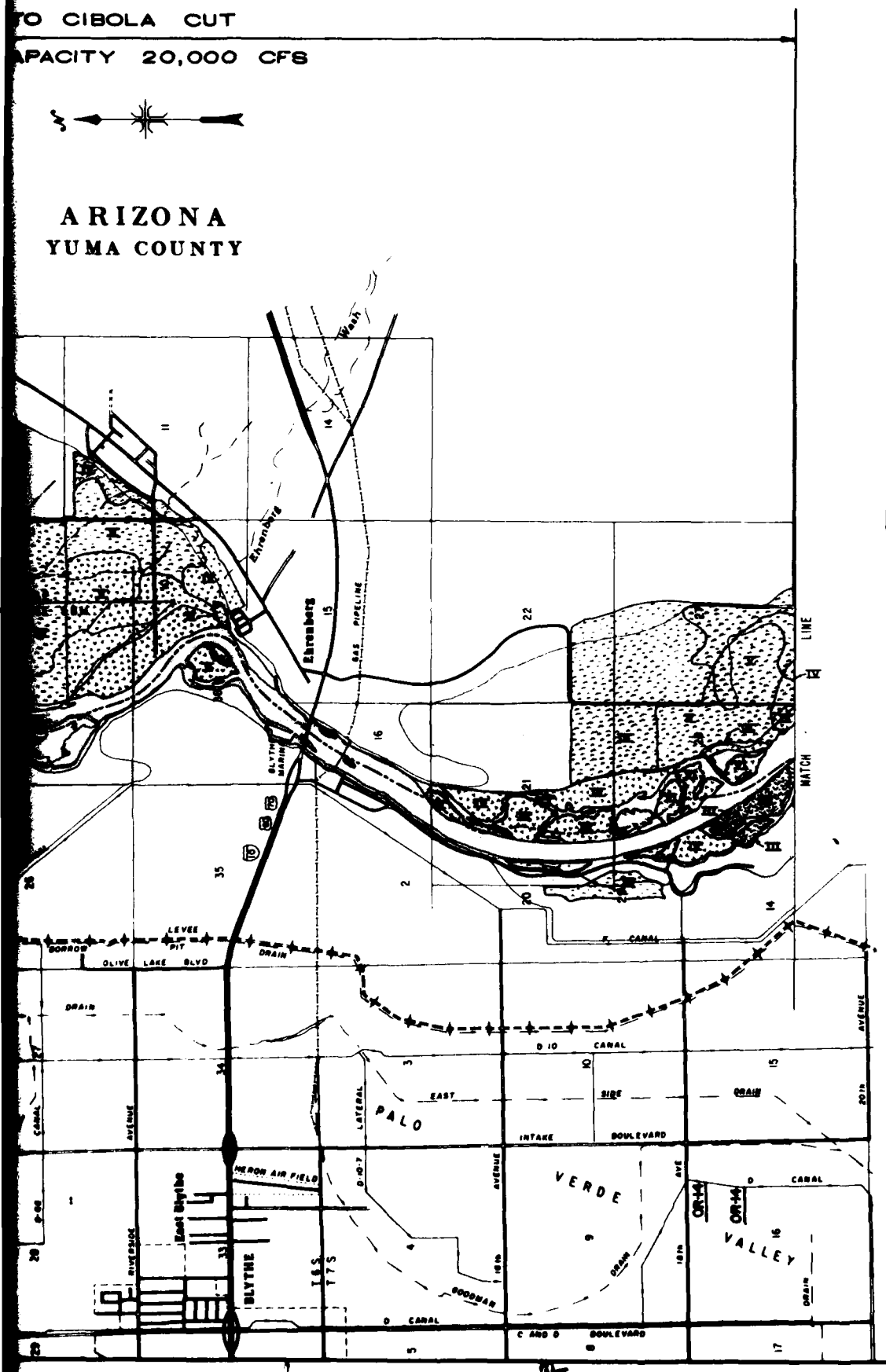

HEADGATE ROCK DAM TO CIBOLA CUT
NONINUNDATING CHANNEL CAPACITY 20,000 CF
ARIZONA
YUMA COUNTY
CALIFORNIA
RIVERSIDE COUNTY
COLORADO RIVER
INDIAN RESERVATION
COLLIS MAYFLOWER COUNTY PARK
OLIVE LAKE DRAIN
PALO VERDE VALLEY
EAST SIDE DRAIN
OLIVE LAKE BLVD
INTAKE BOULEVARD
BLYTHE
East Blythe

TO CIBOLA CUT

APACITY 20,000 CFS

EXPL

ARIZONA
YUMA COUNTY



VEGETATION

SCRE
AS
SALT
HONE
WILL
AS
MARS
SALT
AS

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BY LEV

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COLORADO RIVER FRONT

COLORA

DAVIS DAM TO INTE

COLORADO RIVER FI

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SHEET

OC

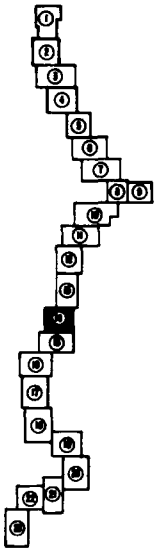
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VEGETATION

- SCREWBEAN MESQUITE-SALT CEDAR ASSOC
- SALT CEDAR
- HONEY MESQUITE
- WILLOW AND/OR COTTONWOOD ASSOC.
- MARSH
- SALT CEDAR-HONEY MESQUITE ASSOC.

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COLORADO RIVER

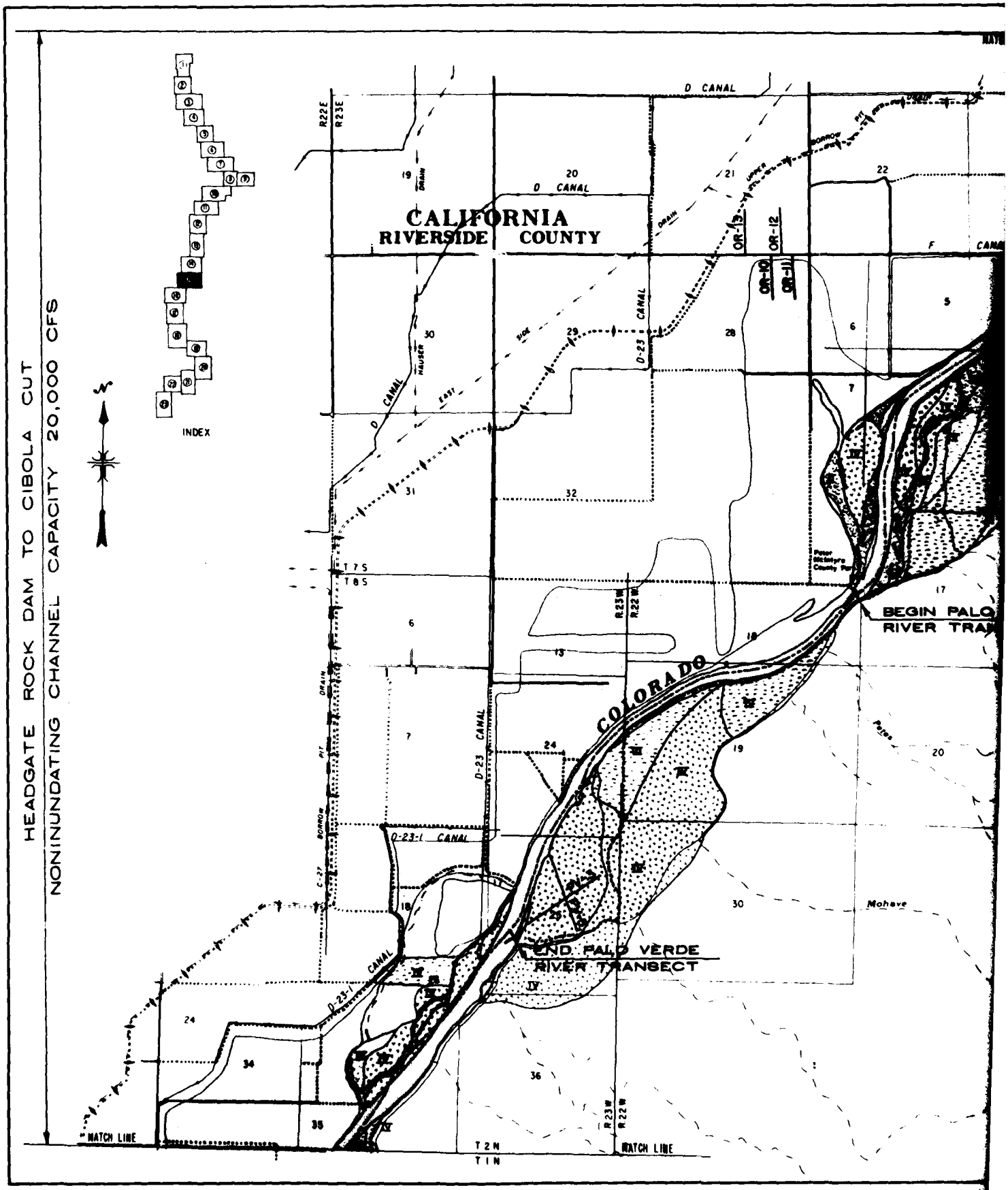
DAVIS DAM TO INTERNATIONAL BOUNDARY

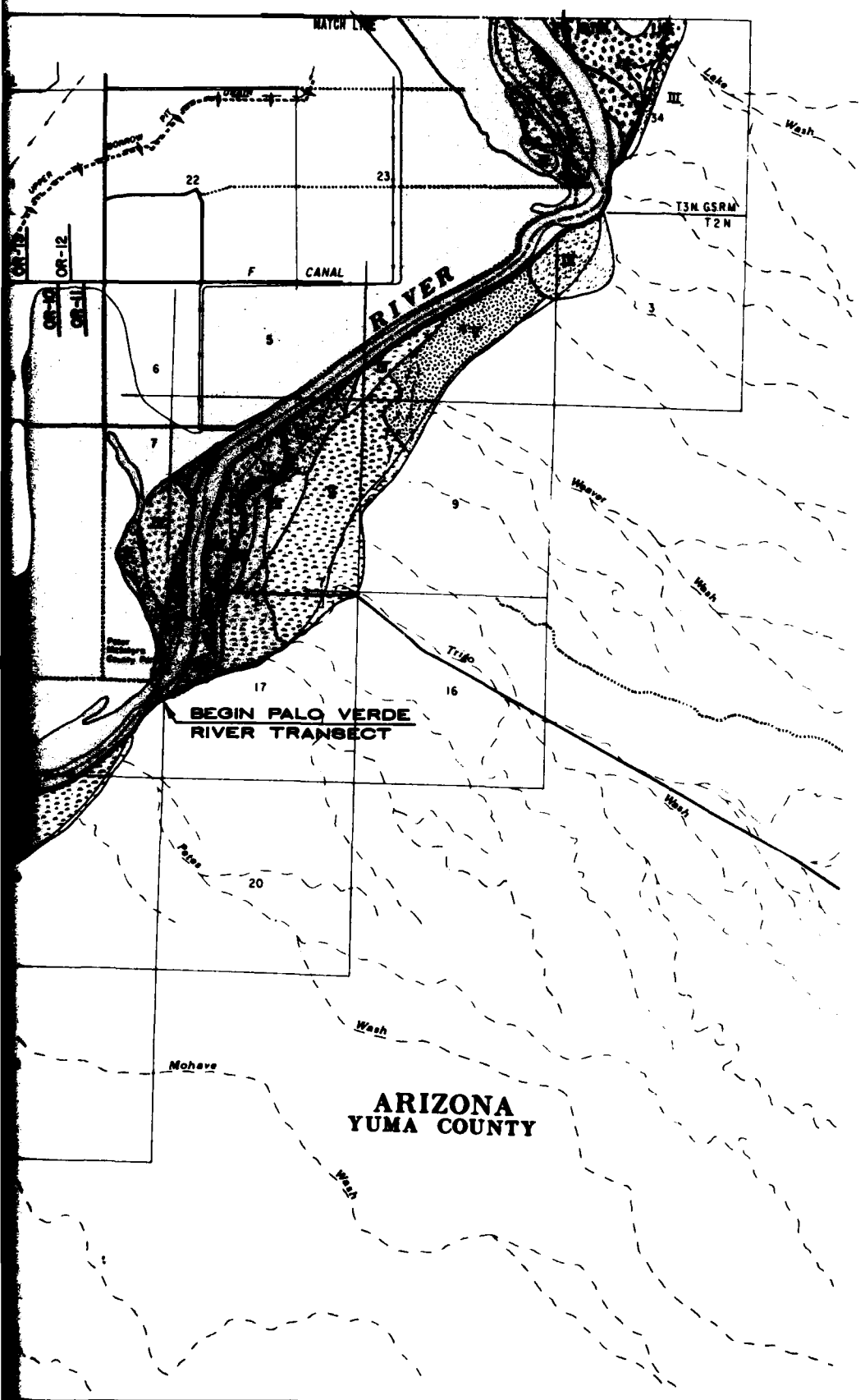
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D-23-1 CANAL
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BORROW
DRAIN
OR-13
OR-12
OR-11
OR-10
R22E
R23E
R23W
R22W
T7S
T8S
T2N
T1N
COLORADO
Mohave
BEGIN PALO
RIVER TRA
END PALO VERDE
RIVER TRANSECT
MATCH LINE
MATCH LINE



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- HONEY MESQUITE
- WILLOW AND/OR COTTON
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DEPARTMENT
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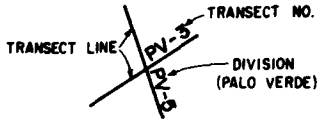
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VEGETATION

- SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
- SALT CEDAR
- HONEY MESQUITE
- WILLOW AND/OR COTTONWOOD-SALT ASSOC.
- MARSH
- ARROWWEED
- SALT CEDAR-HONEY MESQUITE

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- ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

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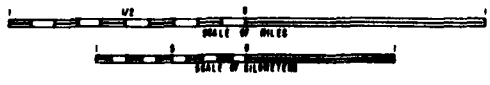
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COLORADO RIVER

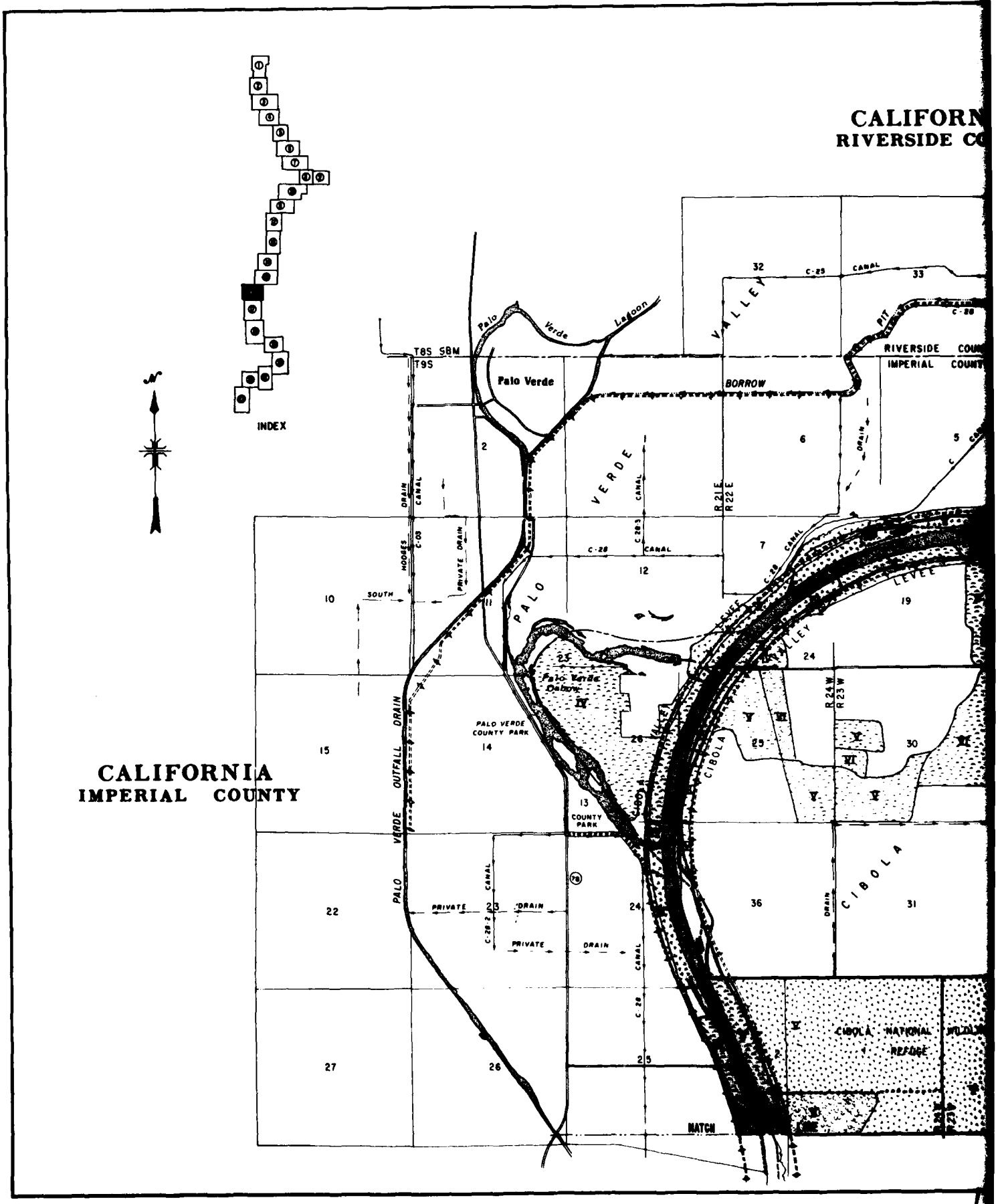
DAVIS DAM TO INTERNATIONAL BOUNDARY

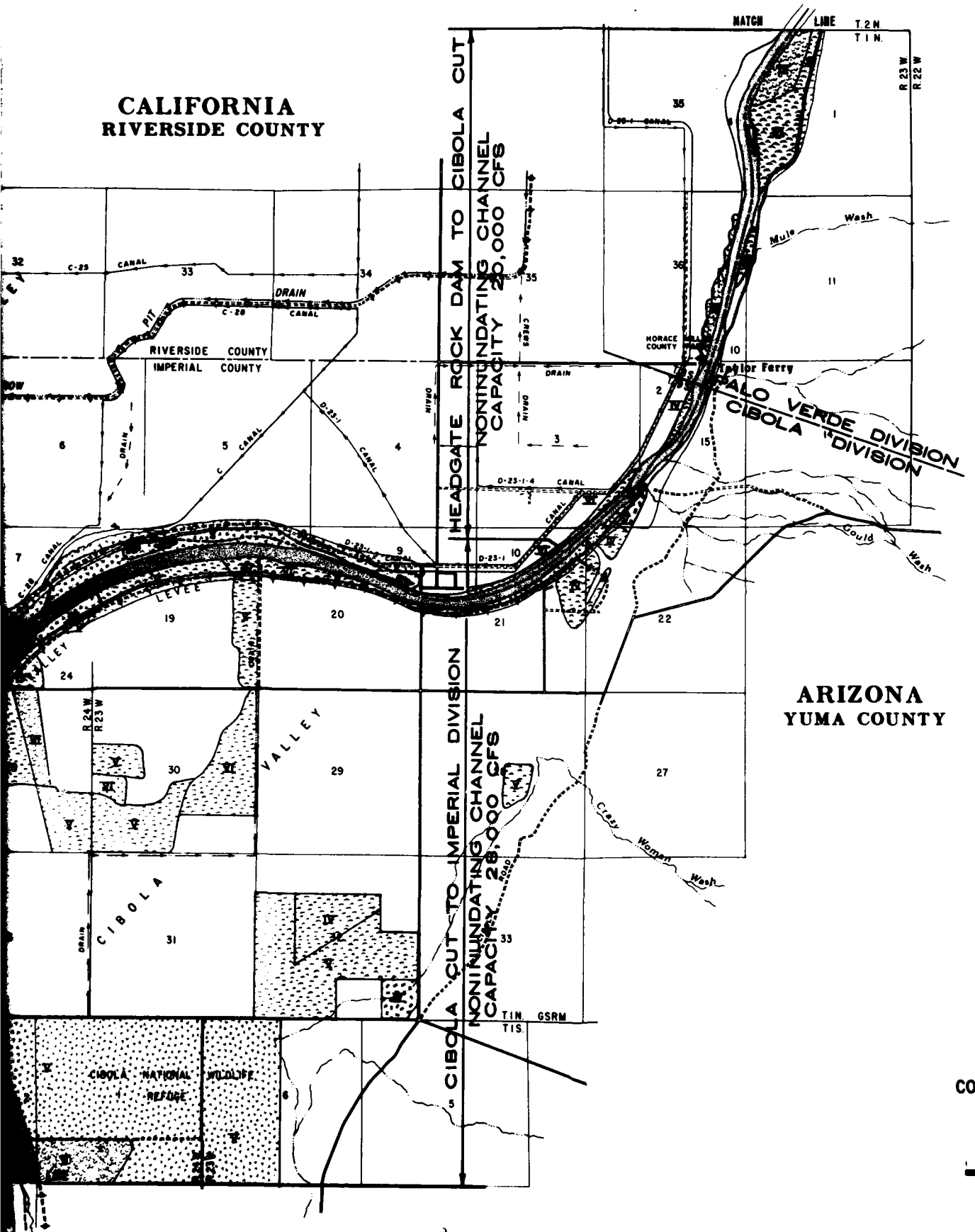
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RIVERSIDE CO
INDEX
CALIFORNIA
IMPERIAL COUNTY
T8S S8M
T9S
Palo Verde
Palo Verde Lagoon
BORROW
PIT
RIVERSIDE COUN
IMPERIAL COUNT
VALLEY
VERDE
PALO
CANAL
DRAIN
LEVEE
R21E
R22E
R24W
R23W
SOUTH
HODGES
C-28
C-28-3
PRIVATE DRAIN
PALO VERDE OUTFALL DRAIN
PALO VERDE COUNTY PARK
COUNTY PARK
CIBOLA
CIBOLA NATIONAL WILDLIFE REFUGE
MATCH
32
33
2
6
5
7
12
10
11
19
24
25
26
29
30
15
14
13
22
23
36
31
27
28


CALIFORNIA
RIVERSIDE COUNTY
MATCH LINE T.2 N
T 1 N.
R 23 W
R 22 W
HEADGATE ROCK DAM TO CIBOLA CUT
NONINUNDATING CHANNEL
CAPACITY 20,000 CFS
CIBOLA CUT TO IMPERIAL DIVISION
NONINUNDATING CHANNEL
CAPACITY 28,000 CFS
RIVERSIDE COUNTY
IMPERIAL COUNTY
HORACE COUNTY
Taylor Ferry
PALO VERDE DIVISION
CIBOLA DIVISION
C-23 CANAL
PIT
DRAIN
C-28 CANAL
C CANAL
D-23-1 CANAL
D-23-1-4 CANAL
LEVEE
VALLEY
CIBOLA VALLEY
Mule Wash
Gould Wash
Cressy Wash
Women
ARIZONA
YUMA COUNTY
R 24 W
R 23 W
T.1 N. GSRM
T.1 S.
CIBOLA NATIONAL WILDLIFE REFUGE
EXPLA
VEGETATION
SCREWBE
ASSOC
SALT CE
HONEY M
WILLOW
ASSOC.
MARSH
ARROWWE
SALT CE
ASSOC.
VEGETATION STRUCTU
APPROXIMATE
WITH 50,000
ADDITIONAL
BY LEVEE
UNITED
DEPARTMENT OF
BUREAU OF
COLORADO RIVER FRONT W
COLORADO
DAVIS DAM TO INTERN
COLORADO RIVER FLO
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- SALT CEDAR
- HONEY MESQUITE
- WILLOW AND/OR COTTONWOOD ASSOC.
- MARSH
- ARROWWEED
- SALT CEDAR - HONEY MESQUITE ASSOC.

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RIZONA
MA COUNTY

- APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE
- ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

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COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

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DAVIS DAM TO INTERNATIONAL BOUNDARY

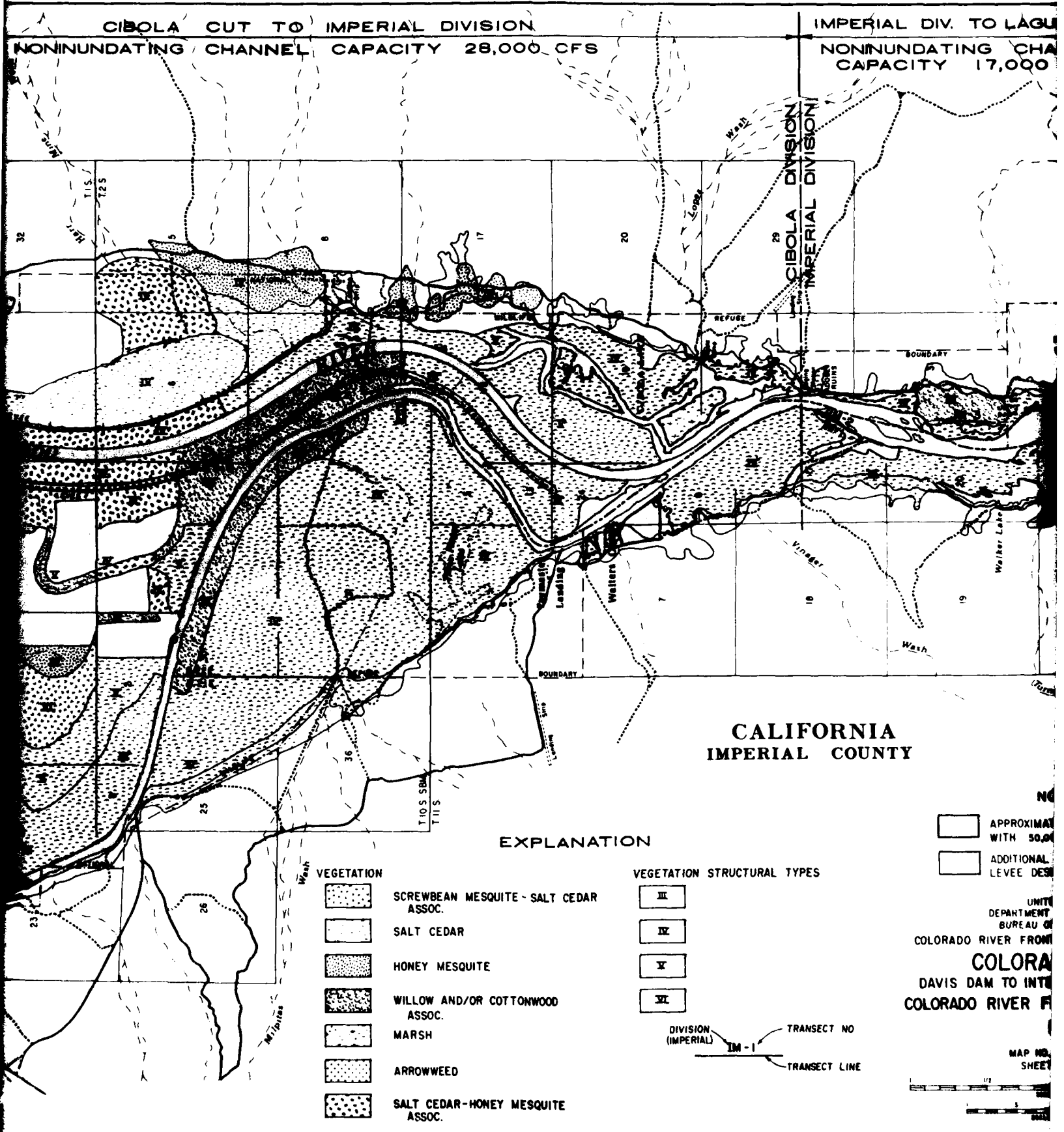
COLORADO RIVER FLOOD CONTROL STUDIES

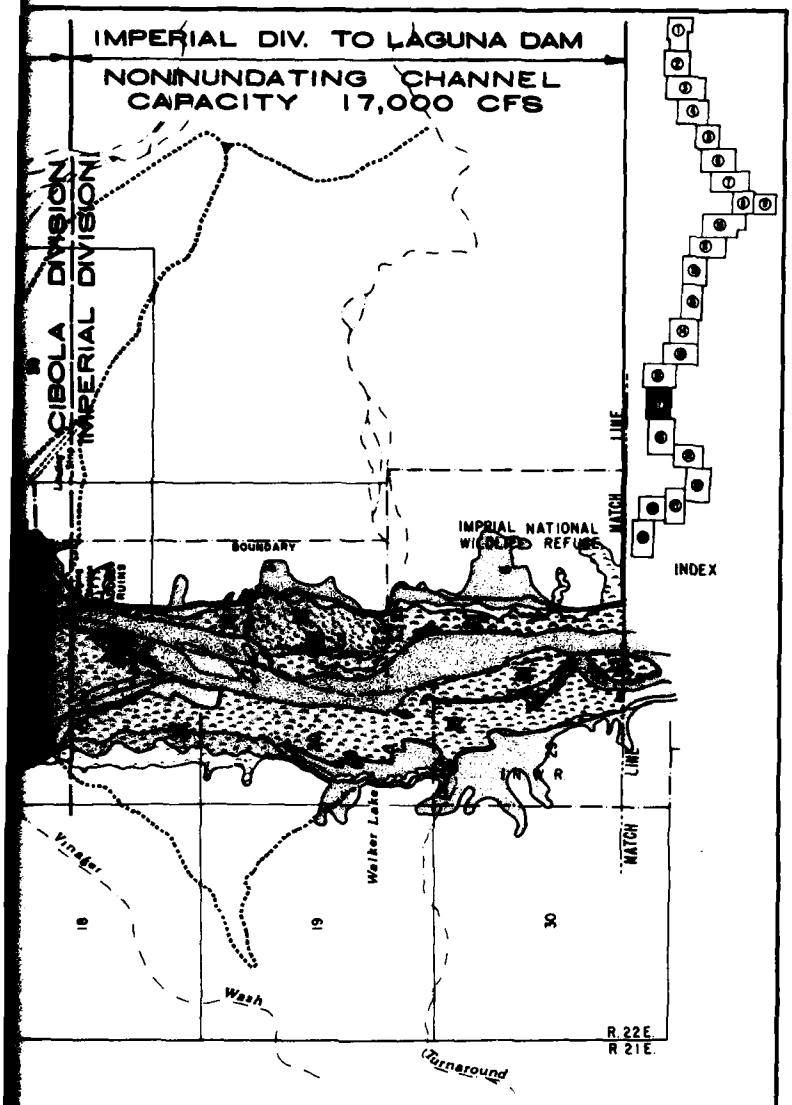
1978

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CIBOLA CUT
NONINUNDATING CHANN
ARIZONA
YUMA COUNTY
COLORADO
RIVER
MATCH LINE
R. 23 W. G.& S.R.M.
R. 24 W.
T.9 S.
T.10 S.
T.1 S.
T.2 S.
VERDE
CIBOLA


CIBOLA CUT TO IMPERIAL DIVISION
NONINUNDATING CHANNEL CAPACITY 28,000 CFS
IMPERIAL DIV. TO LAGU
NONINUNDATING CHA
CAPACITY 17,000
CIBOLA DIVISION
IMPERIAL DIVISION
REFUGE
BOUNDARY
Walters
Landing
Walker Lake
Wash
Milpitas
T.10 S.
T.11 S.
T.1 S.
T.2 S.
CALIFORNIA
IMPERIAL COUNTY
EXPLANATION
VEGETATION
SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
SALT CEDAR
HONEY MESQUITE
WILLOW AND/OR COTTONWOOD ASSOC.
MARSH
ARROWWEED
SALT CEDAR-HONEY MESQUITE ASSOC.
VEGETATION STRUCTURAL TYPES
III
IV
V
VI
DIVISION (IMPERIAL)
IM - 1
TRANSECT NO
TRANSECT LINE
APPROXIMA
WITH 50,0
ADDITIONAL
LEVEE DES
UNITE
DEPARTMENT
BUREAU O
COLORADO RIVER FRON
COLORA
DAVIS DAM TO INT
COLORADO RIVER F
MAP NO.
SHEET



LIFORNIA
IAL COUNTY

NOTE

APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE

ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

L TYPES

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

COLORADO RIVER FLOOD CONTOL STUDIES

TRANSECT NO.

1978

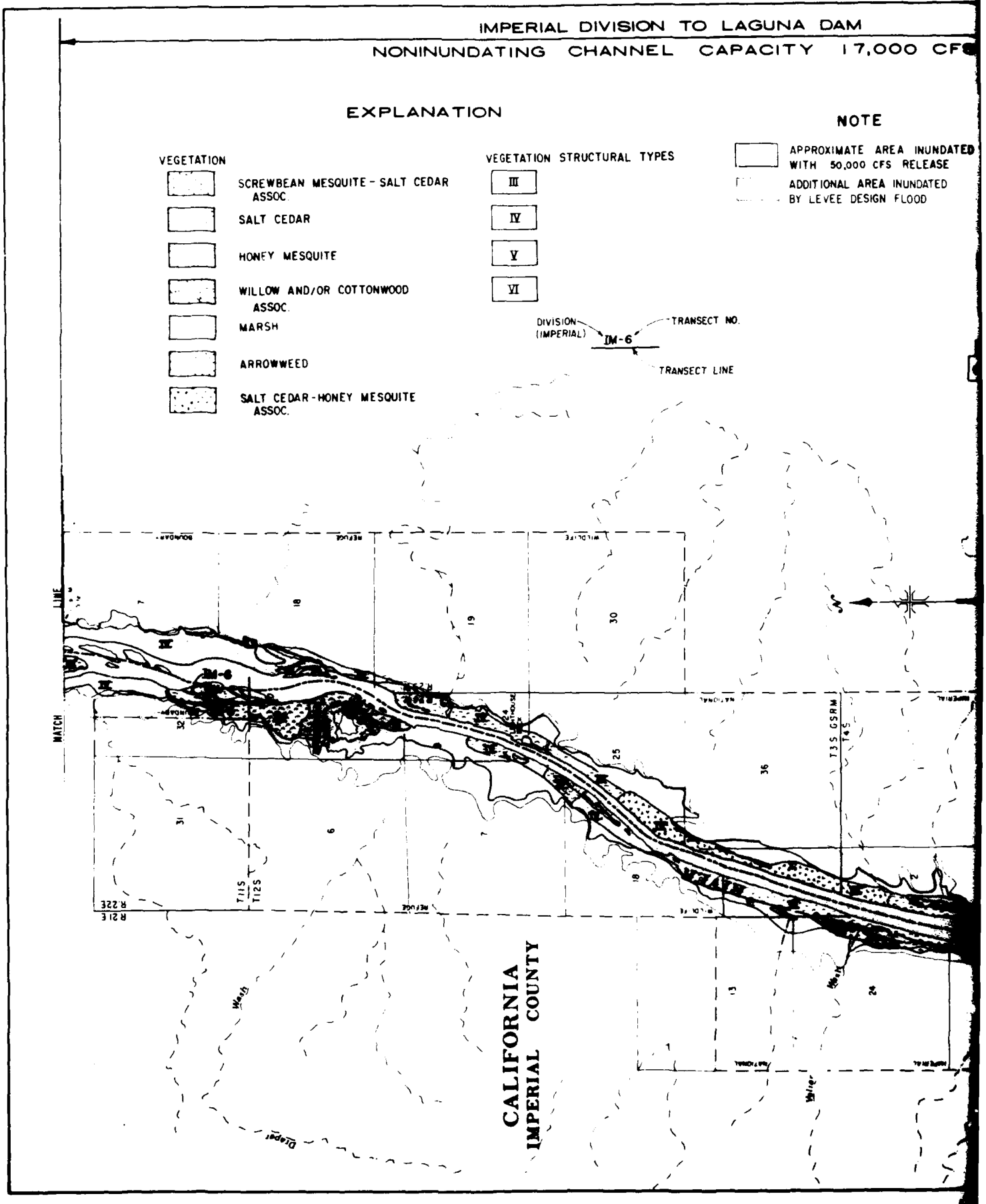
TRANSECT LINE

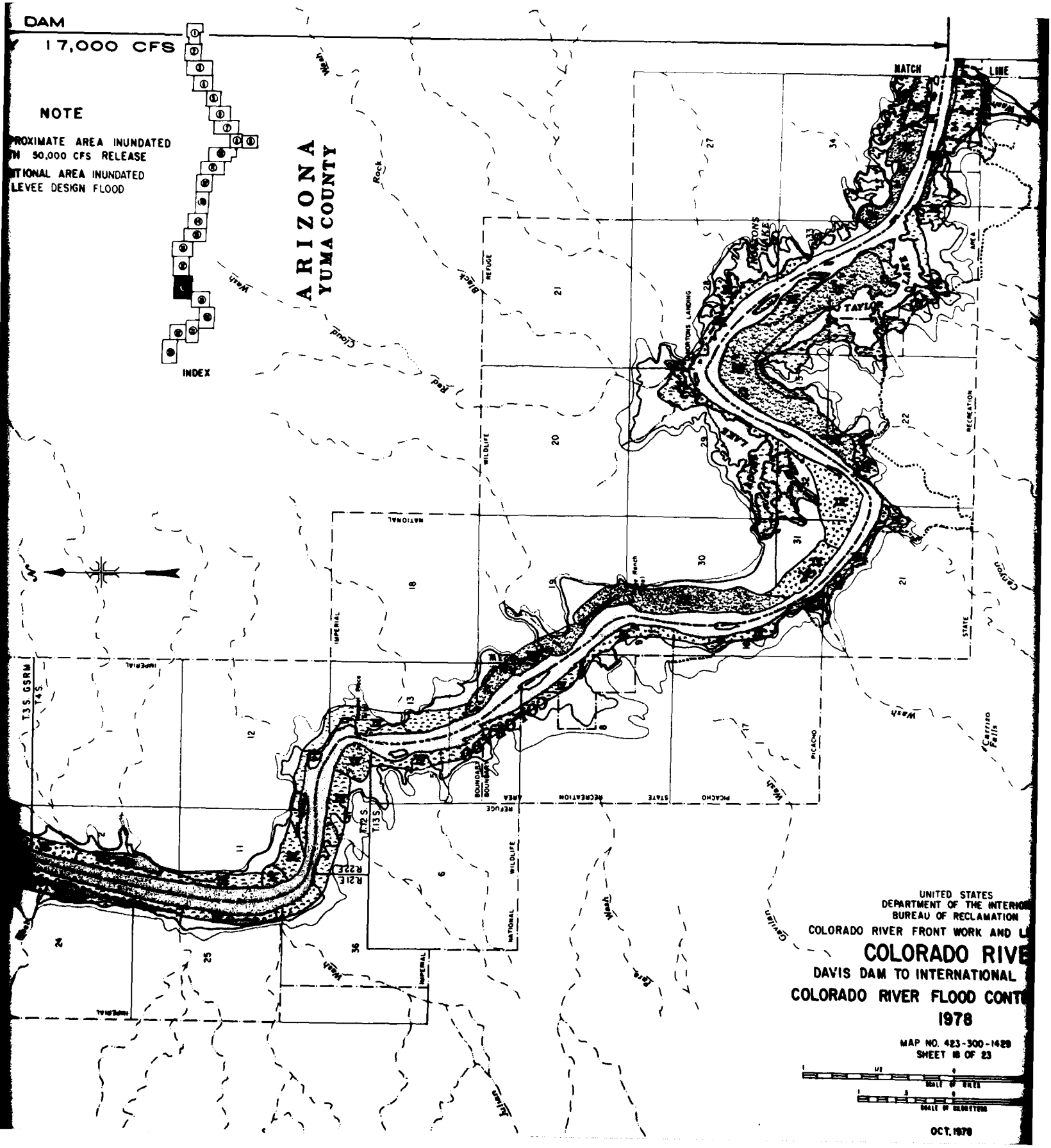
MAP NO. 423-300-1428
SHEET 17 OF 23

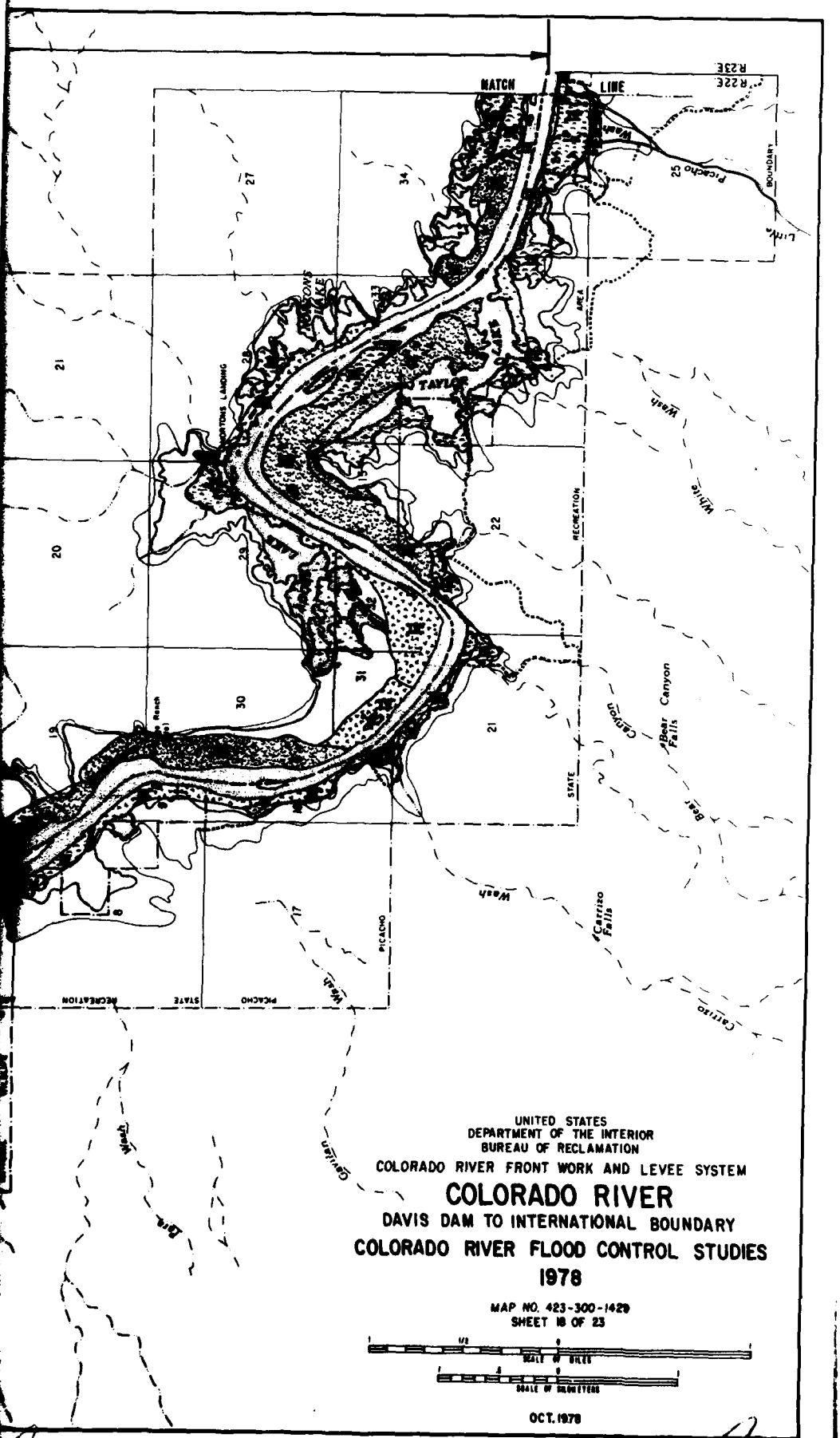
SCALE OF MILES

SCALE OF KILOMETERS

OCT. 1978


IMPERIAL DIVISION TO LAGUNA DAM
NONINUNDATING CHANNEL CAPACITY 17,000 CFS
EXPLANATION
VEGETATION
SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
SALT CEDAR
HONEY MESQUITE
WILLOW AND/OR COTTONWOOD ASSOC.
MARSH
ARROWWEED
SALT CEDAR - HONEY MESQUITE ASSOC.
VEGETATION STRUCTURAL TYPES
III
IV
V
VI
DIVISION (IMPERIAL)
IM-6
TRANSECT NO.
TRANSECT LINE
NOTE
APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE
ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD
MATCH LINE
IM-6
T11S
T12S
R22E
R21E
T3S
T4S
CALIFORNIA
IMPERIAL COUNTY


DAM
17,000 CFS
NOTE
PROXIMATE AREA INUNDATED
M 50,000 CFS RELEASE
TIONAL AREA INUNDATED
LEVEE DESIGN FLOOD
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ARIZONA
YUMA COUNTY
MATCH LINE
TAYLOR LAKE
LAKE
WILDLIFE REFUGE
RECREATION AREA
STATE PICACHO
IMPERIAL NATIONAL
BOUNDARY
T.3 S. G.S.R.M.
T.4 S.
T.12 S.
T.13 S.
R.21 E.
R.22 E.
Rock
Cloud
Black
Wash
Canyon
Picacho
Carrizo Falls
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK AND L
COLORADO RIVE
DAVIS DAM TO INTERNATIONAL
COLORADO RIVER FLOOD CONT
1978
MAP NO. 423-300-1429
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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

COLORADO RIVER FLOOD CONTROL STUDIES

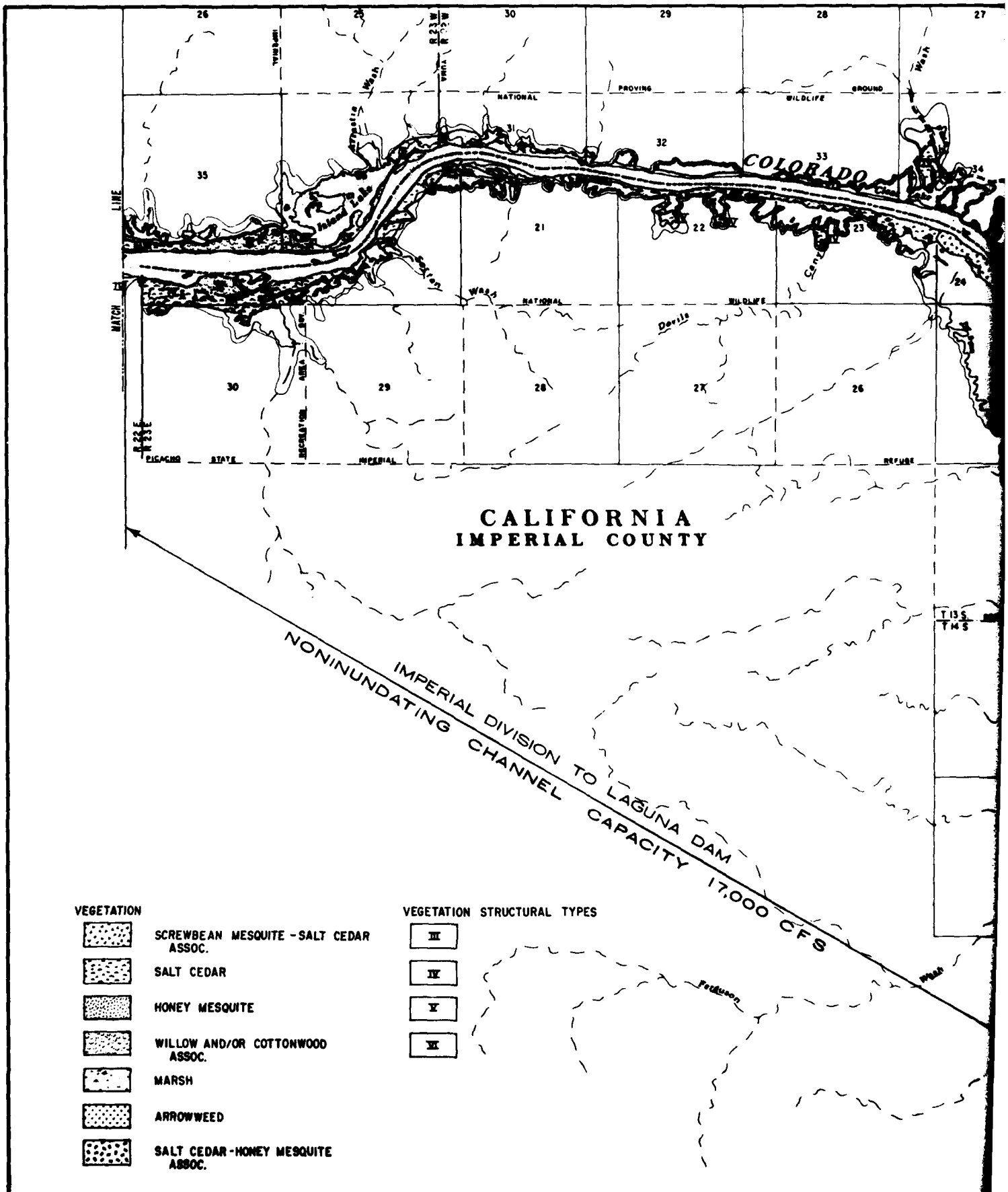
1978

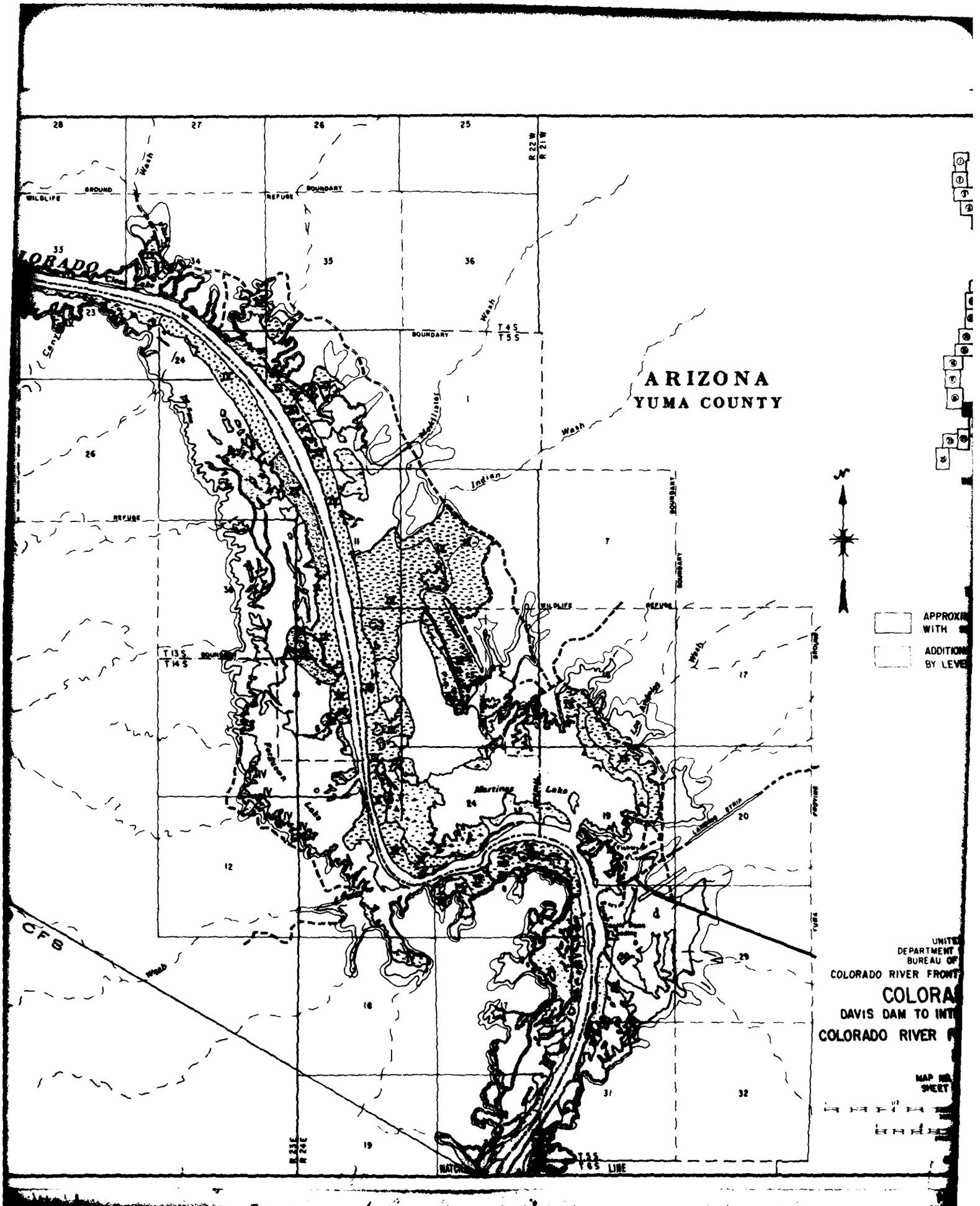
MAP NO. 423-300-1429
SHEET 18 OF 23

SCALE OF MILES

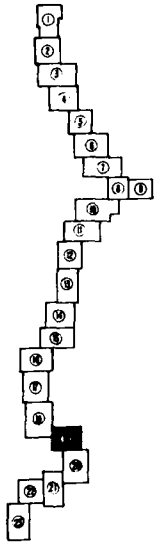
SCALE OF KILOMETERS

OCT. 1978


CALIFORNIA
IMPERIAL COUNTY
COLORADO
NONINUNDATING CHANNEL CAPACITY 17,000 CFS
IMPERIAL DIVISION TO LAGUNA DAM
VEGETATION
SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
SALT CEDAR
HONEY MESQUITE
WILLOW AND/OR COTTONWOOD ASSOC.
MARSH
ARROWWEED
SALT CEDAR - HONEY MESQUITE ASSOC.
VEGETATION STRUCTURAL TYPES
III
IV
V
VI


ARIZONA
YUMA COUNTY
COLORADO RIVER
Martinez Lake
Indian Wash
R 22 W
R 21 W
T 4 S
T 5 S
T 13 S
T 14 S
R 23 E
R 24 E
T 35
T 65
LINE
CFB
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DAVIS DAM TO INT
COLORADO RIVER

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COUNTY



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ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

COLORADO RIVER FLOOD CONTROL STUDIES

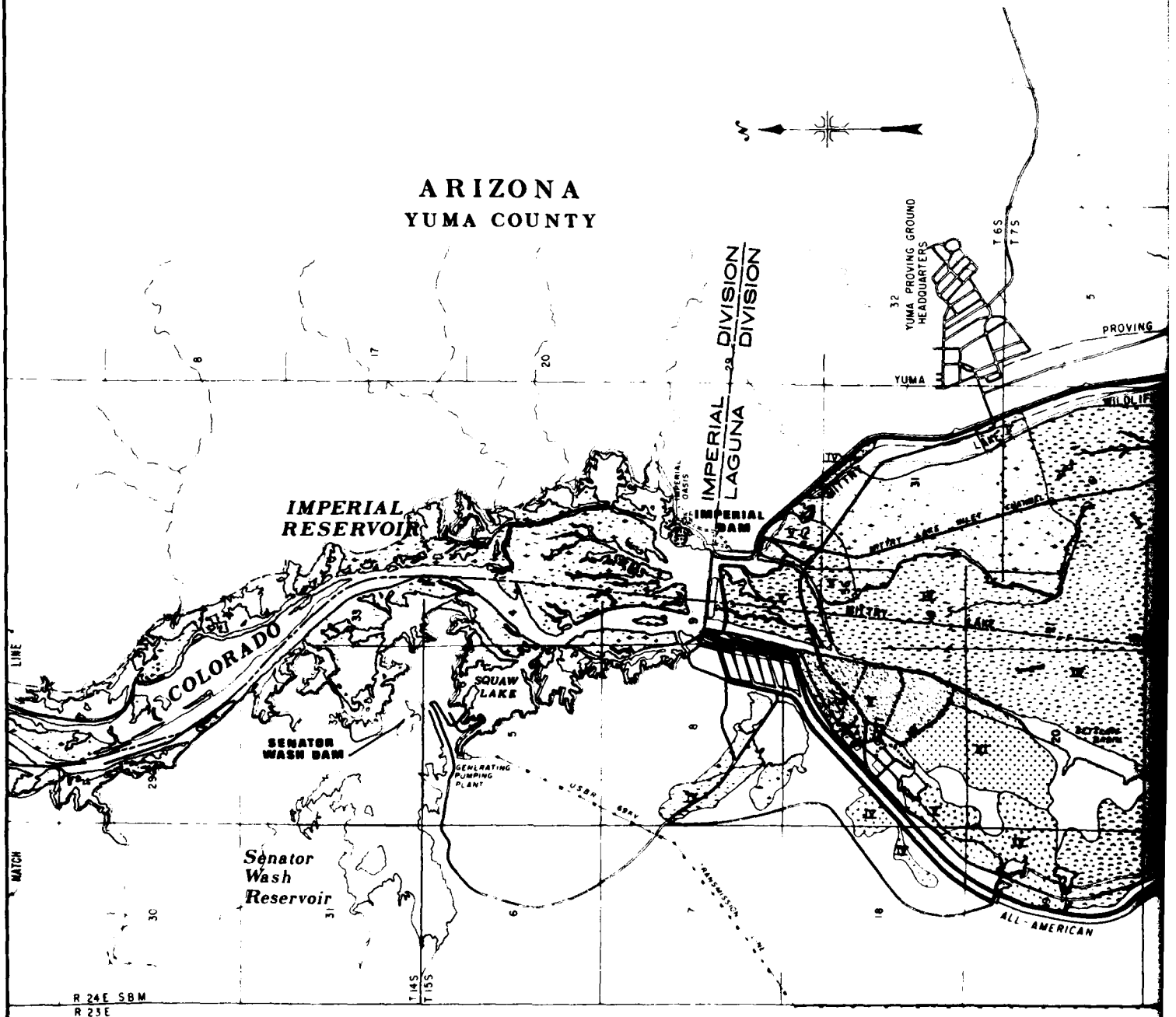
1978

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SCALE OF MILES

SCALE OF KILOMETERS

OCT. 1978



NOTE

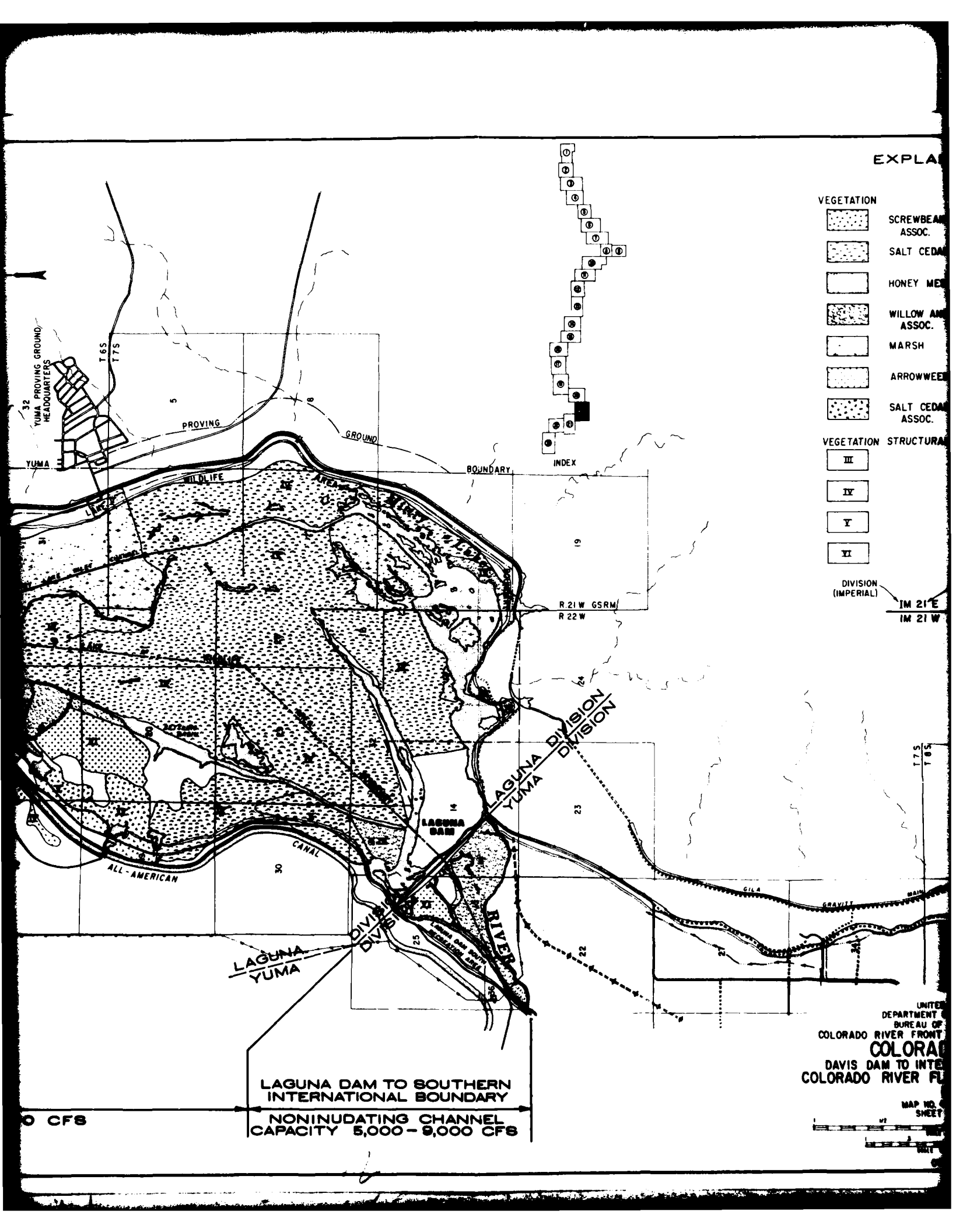
APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE

ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

CALIFORNIA
IMPERIAL COUNTY

IMPERIAL DIVISION TO LAGUNA DAM

NONINUNDATING CHANNEL CAPACITY 17,000 CFS


EXPLA
VEGETATION
SCREWBEA ASSOC.
SALT CEDA
HONEY ME
WILLOW A ASSOC.
MARSH
ARROWWEE
SALT CEDA ASSOC.
VEGETATION STRUCTURA
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IV
V
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IM 21 W
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T 6 S
T 7 S
PROVING
GROUND
YUMA
BOUNDARY
WILDLIFE
AREA
R 21 W GSRM
R 22 W
LAGUNA DIVISION
YUMA DIVISION
LAGUNA DAM
CANAL
ALL-AMERICAN
LAGUNA
YUMA
DIVISION
RIVER
T 7 S
T 8 S
GILA
GRAVITY
LAGUNA DAM TO SOUTHERN INTERNATIONAL BOUNDARY
NONINUDATING CHANNEL
CAPACITY 5,000 - 9,000 CFS
O CFS
UNITED
DEPARTMENT
BUREAU OF
COLORADO RIVER FRONT
COLORA
DAVIS DAM TO INTE
COLORADO RIVER FL
MAP NO.
SHEET

EXPLANATION

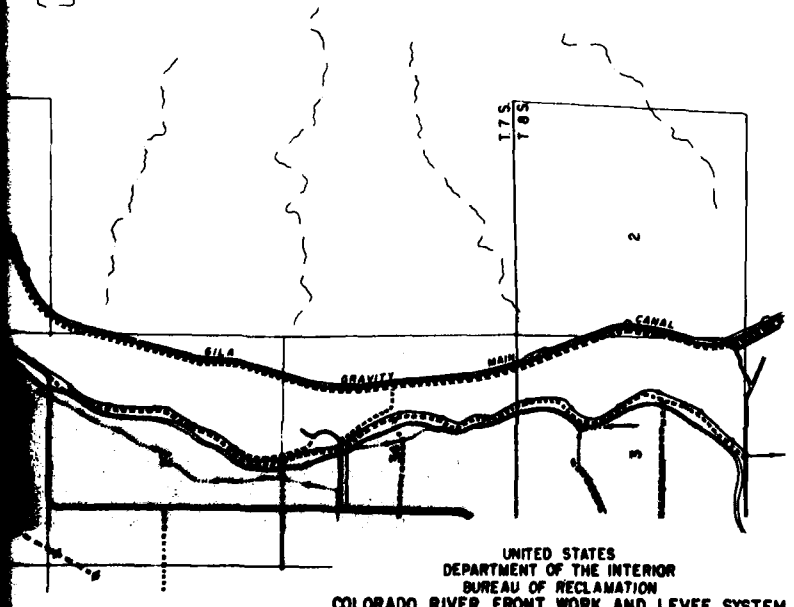
VEGETATION

- SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
- SALT CEDAR
- HONEY MESQUITE
- WILLOW AND/OR COTTONWOOD ASSOC.
- MARSH
- ARROWWEED
- SALT CEDAR-HONEY MESQUITE ASSOC.

VEGETATION STRUCTURAL TYPES

- III
- IV
- V
- VI

DIVISION (IMPERIAL) — IM 21 E / IM 21 W — TRANSECT NO. — TRANSECT LINE



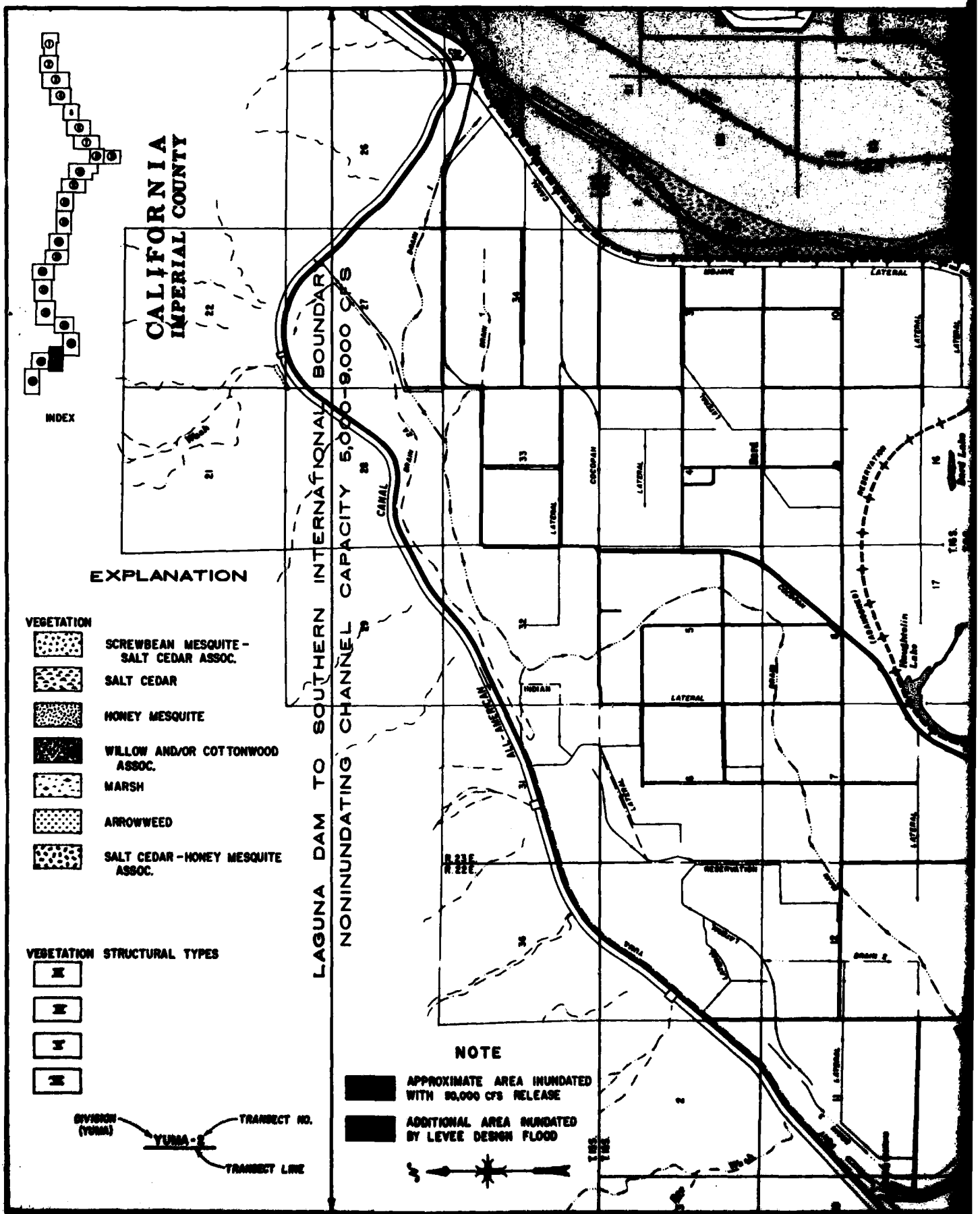
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

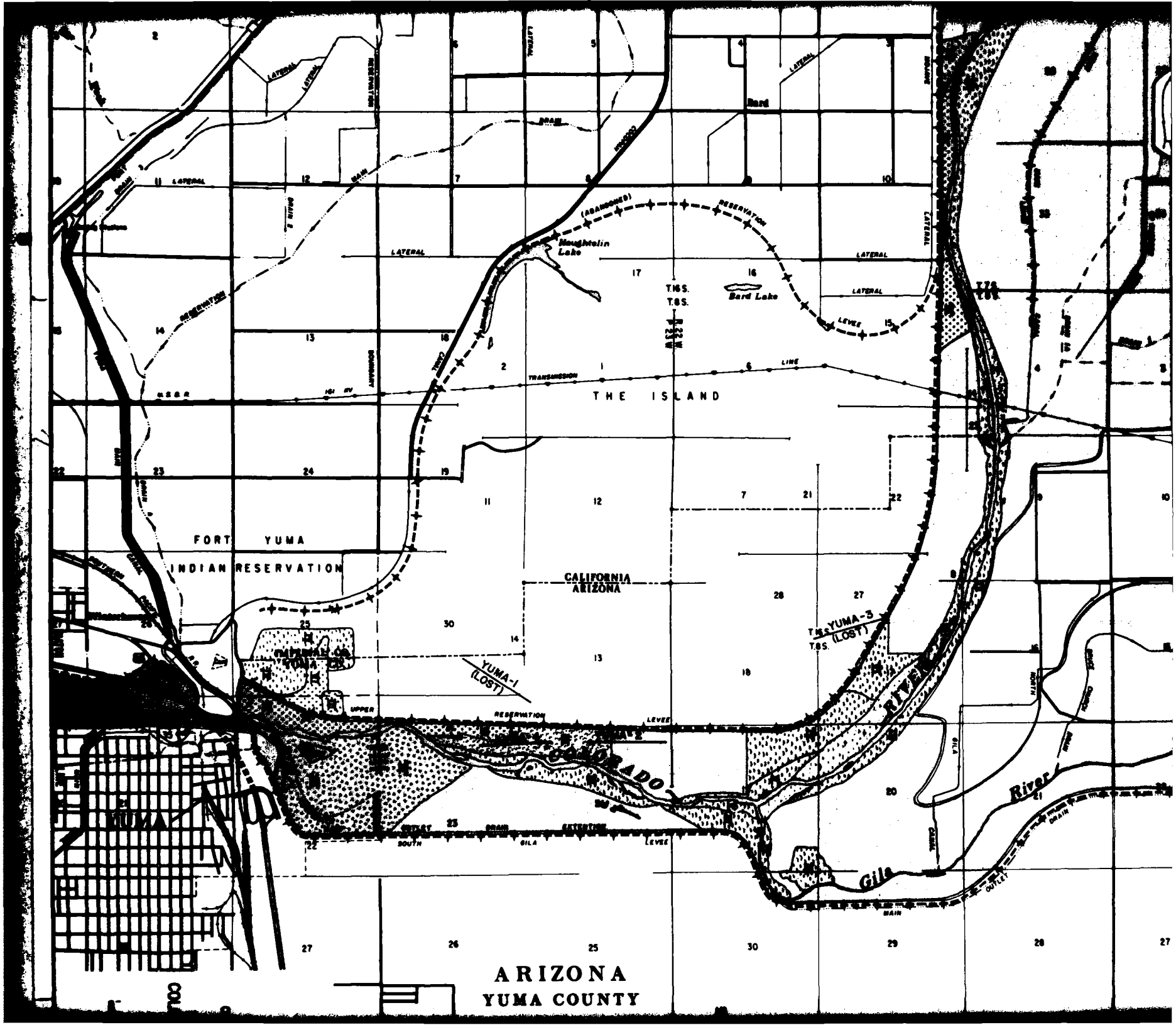
COLORADO RIVER

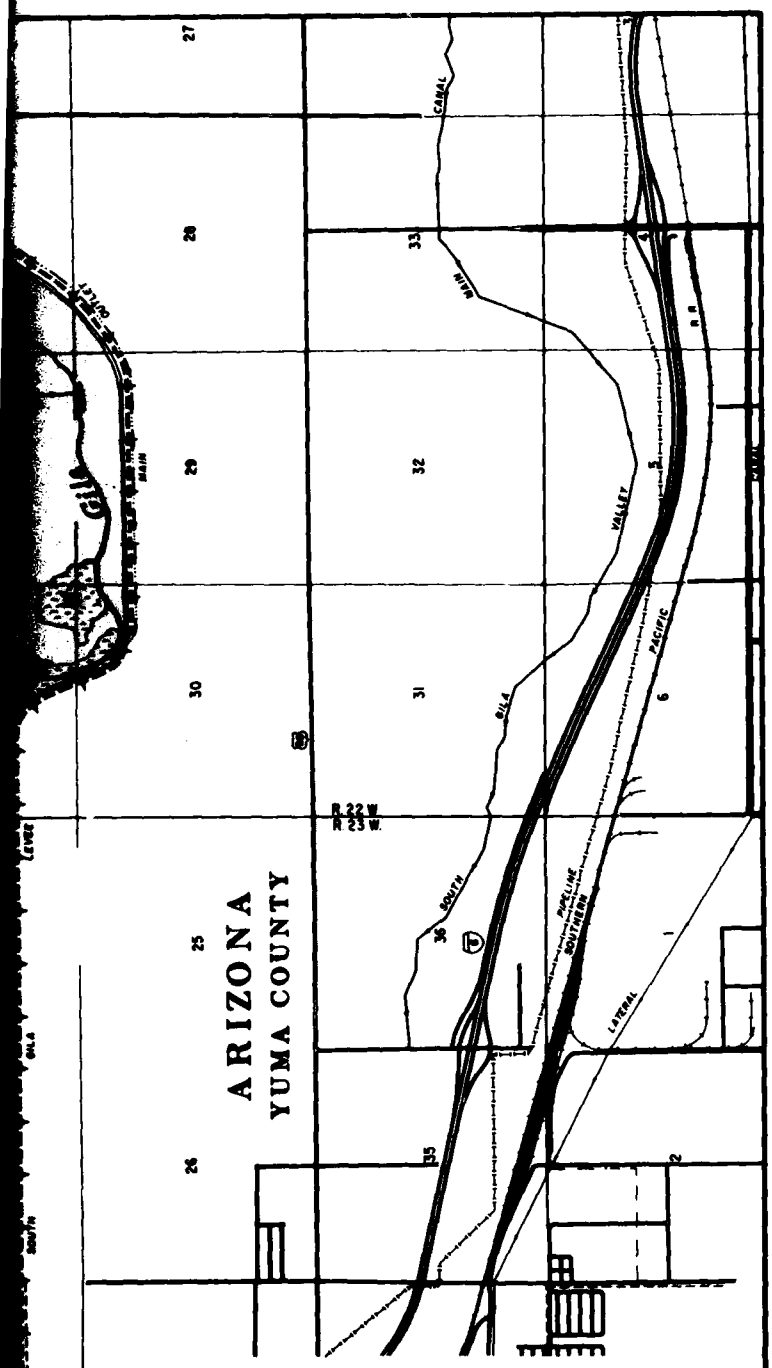
DAVIS DAM TO INTERNATIONAL BOUNDARY
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1978

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OCT. 1978


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SALT CEDAR
HONEY MESQUITE
WILLOW AND/OR COTTONWOOD ASSOC.
MARSH
ARROWWEED
SALT CEDAR - HONEY MESQUITE ASSOC.
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II
III
IV
DIVISION (YUMA)
YUMA-2
TRANSECT NO.
TRANSECT LINE
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R.22E.
T.8S.
T.9S.
T.10S.
T.11S.
ALL-AMERICAN
CANAL
INDIAN
RESERVATION
COCOPAH
LATERAL
DRAIN
Roughhalin Lake
Red Lake


THE ISLAND
FORT YUMA
INDIAN RESERVATION
CALIFORNIA
ARIZONA
Houghtolin Lake
Bard Lake
T.16S.
T.8S.
YUMA-1 (LOST)
T.16S. YUMA-3 (LOST)
T.8S.
COLORADO RIVER
Gila River
YUMA
ARIZONA
YUMA COUNTY



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

COLORADO RIVER

DAVIS DAM TO INTERNATIONAL BOUNDARY

COLORADO RIVER FLOOD CONTROL STUDIES

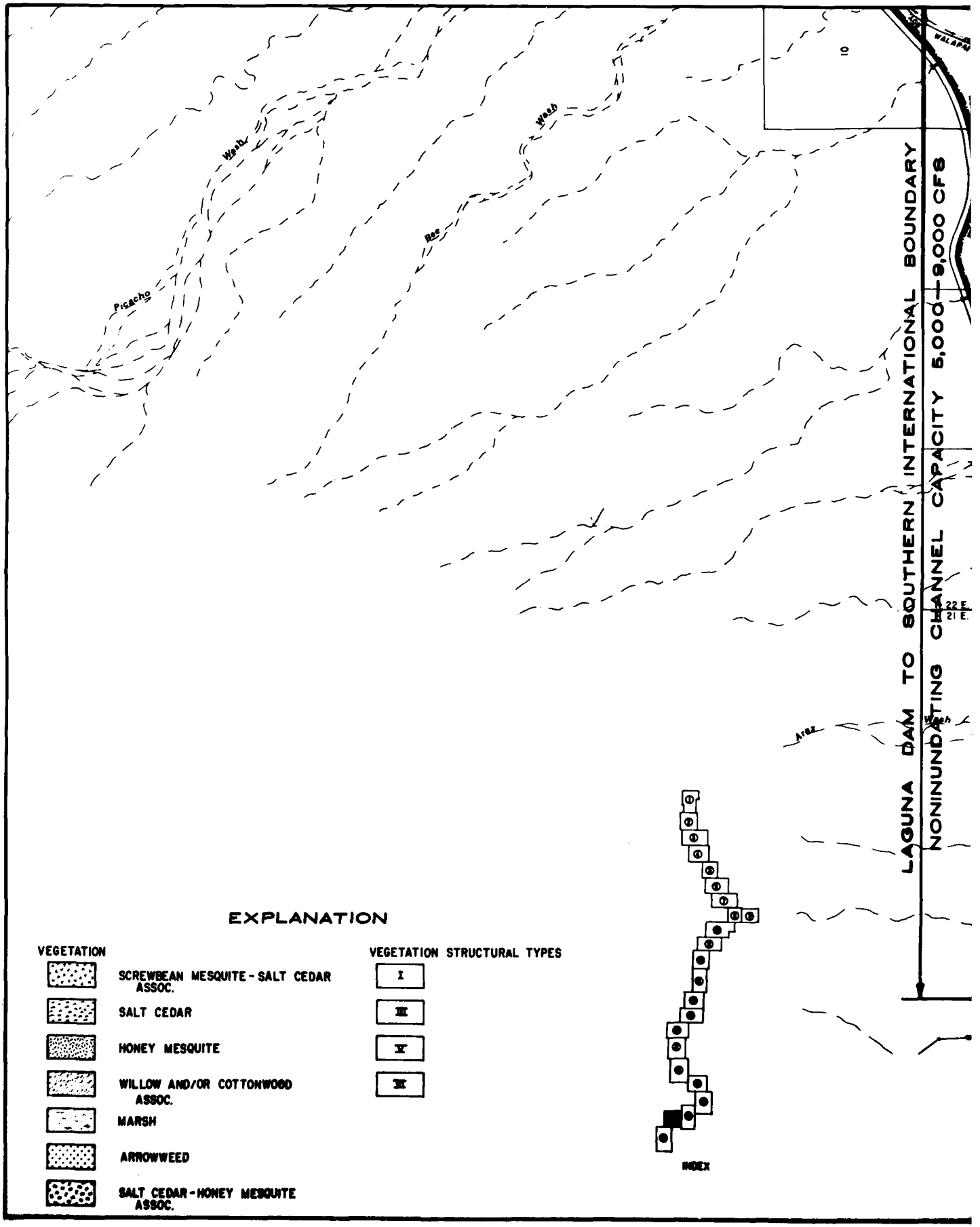
1978

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SCALE OF MILES

SCALE OF KILOMETERS

OCT. 1978


Wash
Wash
Bee
Pisacho
Arroz
LAGUNA DAM TO SOUTHERN INTERNATIONAL BOUNDARY
NONINUNDATING CHANNEL CAPACITY 5,000 - 8,000 CFS
22 E.
21 E.
EXPLANATION
VEGETATION
SCREWBEAN MESQUITE - SALT CEDAR ASSOC.
SALT CEDAR
HONEY MESQUITE
WILLOW AND/OR COTTONWOOD ASSOC.
MARSH
ARROWWEED
SALT CEDAR - HONEY MESQUITE ASSOC.
VEGETATION STRUCTURAL TYPES
I
III
V
VI
INDEX

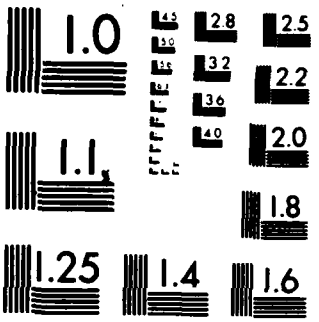
UNITED S
DEPARTMENT OF
BUREAU OF R
COLORADO RIVER FRONT WO
COLORADO
DAVIS DAM TO INTERN
COLORADO RIVER FLOO
19
MAP NO. 4
SHEET

OCT.

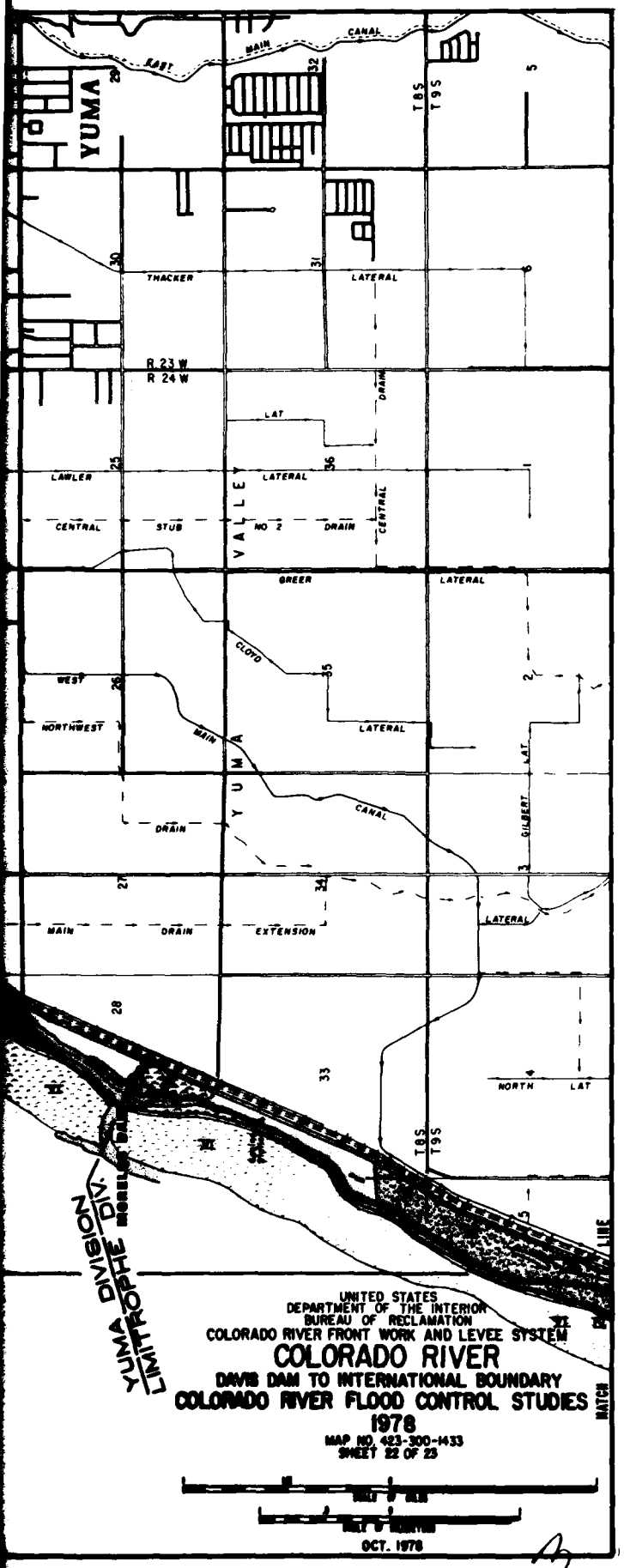
AD-A132 464 COLORADO RIVER BASIN HOVER DAM - REVIEW OF FLOOD CONTROL REGULATION(U) ARMY ENGINEER DISTRICT LOS ANGELES CALIF JUL 82 5/5

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLORADO RIVER FRONT WORK AND LEVEE SYSTEM

COLORADO RIVER

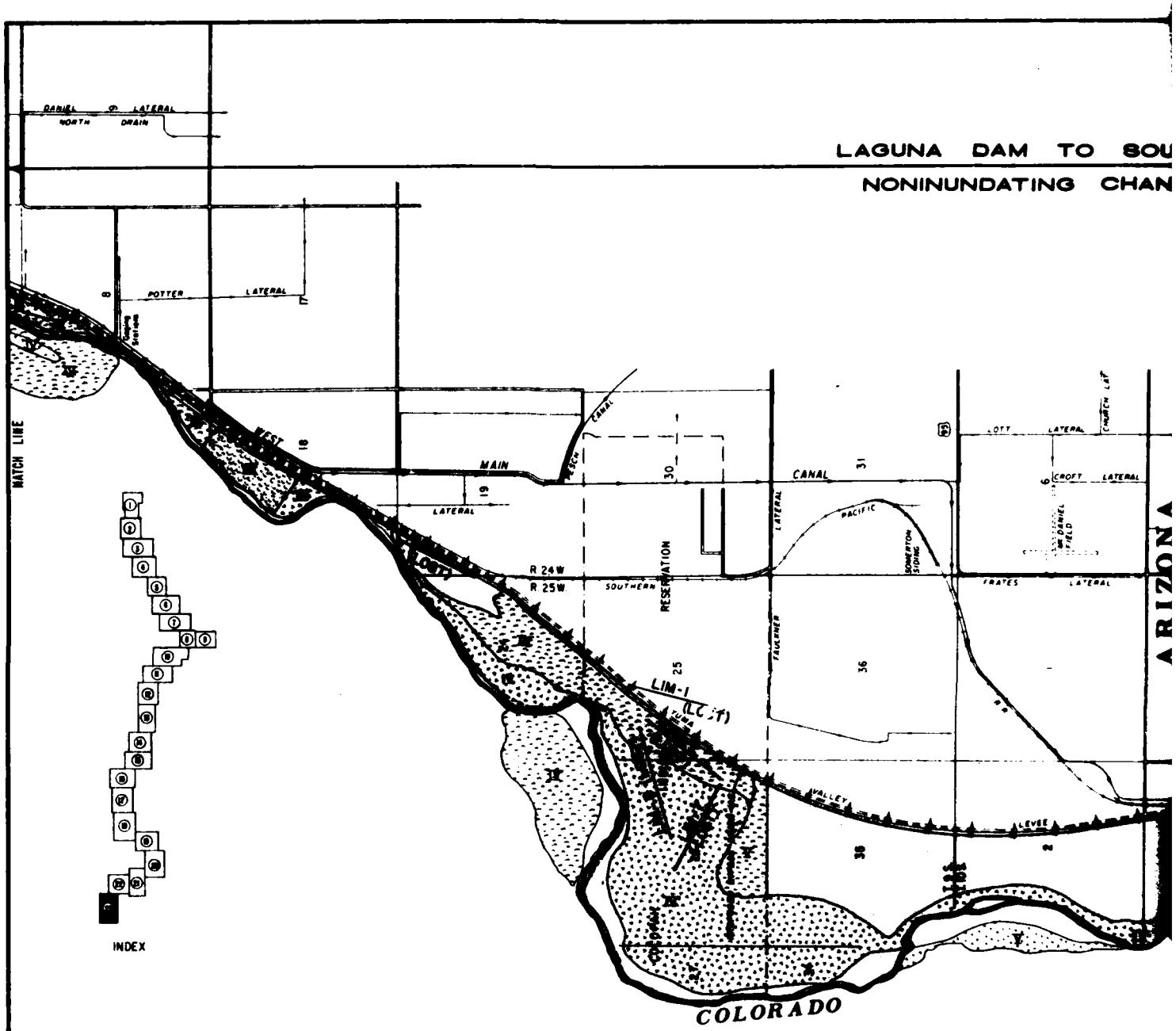
DAVIS DAM TO INTERNATIONAL BOUNDARY

COLORADO RIVER FLOOD CONTROL STUDIES

1978

MAP NO. 423-300-1433
SHEET 22 OF 25

OCT. 1978



EXPLANATION

VEGETATION

- SCREWBEAN MESQUITE-SALT CEDAR ASSOC.
- SALT CEDAR
- HONEY MESQUITE
- WILLOW AND/OR COTTONWOOD ASSOC.
- MARSH
- ARROWWEED
- SALT CEDAR-HONEY MESQUITE

VEGETATION STRUCTURAL TYPES

- III
- IV
- V
- VI

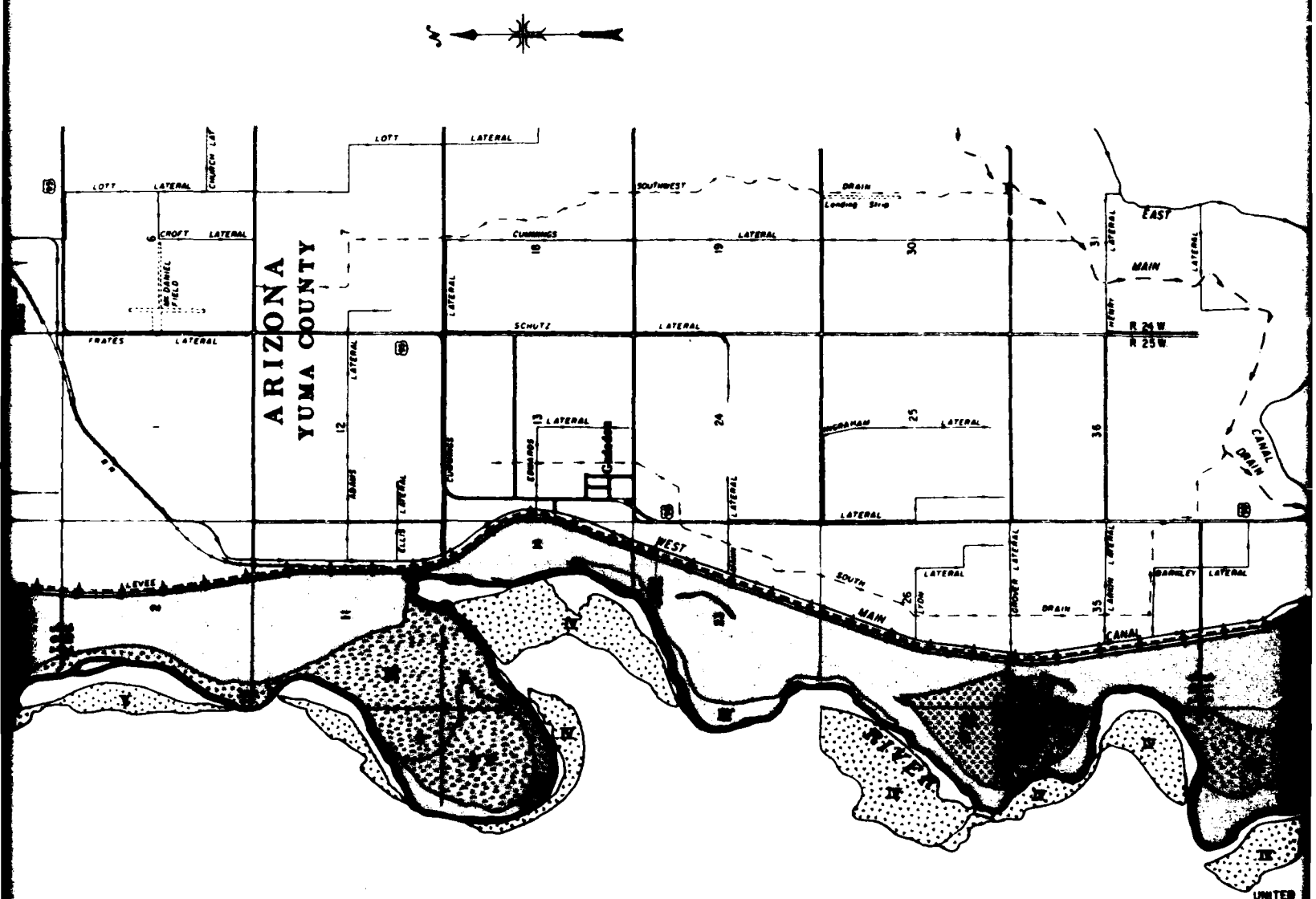
DIVISION (LIMITROPHE) — TRANSECT NO.
LIM - 1
(LOST) — TRANSECT LINE

NOTE

- APPROXIMATE AREA INUNDATED WITH 50,000 CFS RELEASE
- ADDITIONAL AREA INUNDATED BY LEVEE DESIGN FLOOD

NA DAM TO SOUTHERN INTERNATIONAL BOUNDARY

NINUNDATING CHANNEL CAPACITY 5,000–9,000 CFS



NOTE

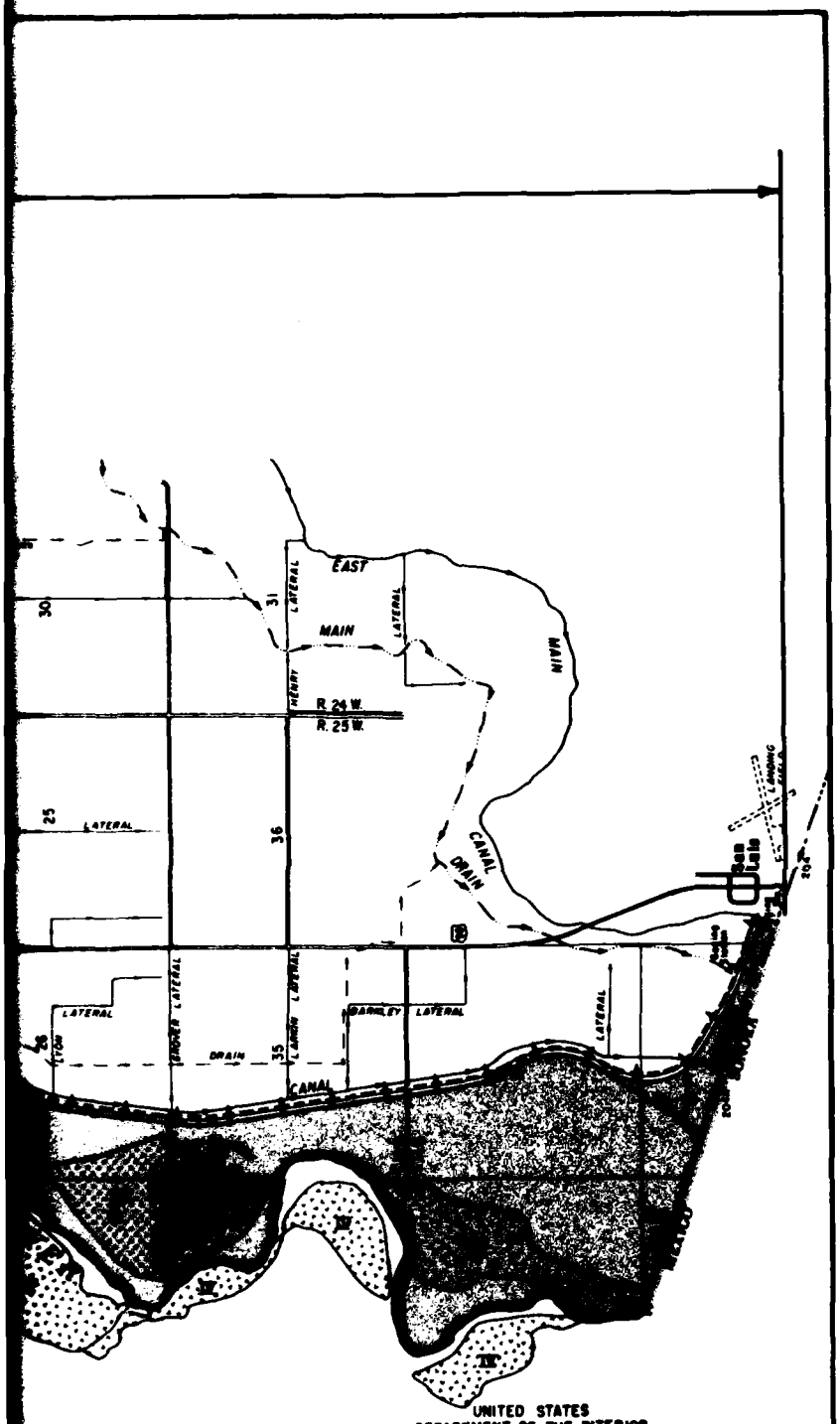
XIMATE AREA INUNDATED
80,000 CFS RELEASE

ONAL AREA INUNDATED
VEE DESIGN FLOOD

UNITED
DEPARTMENT
BUREAU OF
COLORADO RIVER FRONT

COLORAD
DAVIS DAM TO INTER
COLORADO RIVER FL

MAP NO.
SHEET


EAST
MAIN
LATERAL
MAIN
HENRY
R. 24 W.
R. 25 W.
30
31
25
36
LATERAL
CANAL
DRAIN
San Luis
LATERAL
BARNEY
LATERAL
LATERAL
26
T10S
DRAIN
35
CANAL
LATERAL
LATERAL
LATER